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Influence of Physico-Geographical Factors on the Variability of Annual River Drainage (Run-Off)

Meteorologiya i Gidrologiya, L. K. Davydov
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"INFLUENCE OF PHYSICO-GEOGRAPHICAL FACTORS ON THE VARIABILITY OF ANNUAL RIVER DRAINAGE (RUN-OFF)"

L. K. Davydov

[Note: the following article, criticizing another, appeared in the "Criticism and Bibliography" section of Meteorology and Hydrology, No. 4 (April 1948), pages 33-5.]

In issue No. 6 of the information symposium "Meteorology and Hydrology" for the year 1947, and also in the monograph "Water Supply of the USSR Rivers, its Fluctuations and the Effect upon It of Physico-geographical Factors", I have analysed the existing theories on the question of influence of physico-geographical factors upon the variability of annual river drainage. As a result of this analysis I came to the conclusion that attempts to establish quantitative relationships between C_{V_y} and influencing factors are frequently of a conjectural nature; and, what is more important, they do not reveal the nature of these relationships. In particular, analyzing the well known formula of D. L. Sokolovskiy, $C_v = a - 0.063 \log(F+1)$, I came to ~~the conclusion~~ be convinced of the erroneous interpretation of the effect of watershed area upon the variability of annual river drainage. By means of analysis of the equation of aqueous balance, I have found the following relationship:

$$C_{V_y} = \frac{C_{V_x}}{\eta} A \qquad (1)$$

where C_{V_x} is the coefficient of variation of annual totals of atmospheric precipitation, η is the drainage coefficient, A is a certain parameter which characterizes the relationships between the annual totals of atmospheric precipitation, magnitude of drainage and total losses, which include evaporation losses and the quantity of moisture accumulation and expenditure within the reservoir [basin].

In criticizing my views on the subject as set forth in the above-cited issue of the information symposium, D. L. Sokolovskiy maintains without any basis that ".....conclusion of L. K. Davydov (concerning the influence of area — L. D.) contradicts the experimental

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data, as well as a number of logical considerations." Where is the error in D. L. Sokolovskiy's position?

It is known that the annual drainage of any river is $y = x - z - u$. It is also known that in the zone of extra moisture a well defined direct relationship obtains between the quantities y and x, which is characterized by high correlation coefficients (r_{yx}) between these quantities. On the other hand, it is also known that in the extra moisture zone, annual evaporation value z is characterized by small variability, and some authors take z as constant in some hydrological calculations. It is obvious that in such a case it is entirely allowable to unify $z \pm u$, calling it z_0 as I did in the above-mentioned analysis. Finally, it is therefore completely evident that, in the zone of extra moisture, variability of annual drainage is determined primarily by the variability of annual totals of precipitation; the part played by $\pm u$ becomes secondary. At the same time the variability of quantity $\pm u$ is hardly determined by the dimensions of watershed area, since the increase of reservoir area not only increases the size of subterranean water reservoir, but, what is more important, there occurs a change in hydrogeological and subsoil conditions. Just these factors determine the nature of variability of the quantity u. If we take into account that in the zone of extra moisture, as well as over the entire plains portion of the European part of our territory, there exists latitudinal zonality in climatic conditions and distribution of subsoil waters, then the role of watershed area as the statistical result of these conditions becomes clear.

In moving southward, with the decrease in subsoil water supply, variation in z begins to have an ever increasing effect upon the variability of $z_0 = z \pm u$, the part played by variability of u becoming minor. At the same time, since the fluctuations of annual river drain-

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age in zones of inadequate moisture are determined primarily by fluctuations of spring water drainage, it is clearly obvious that in this zone also the predominant leading role in the variability of annual drainage is played by climatic factors. As previously, the watershed area plays the part of statistical regulator.

Correctness of this is also well confirmed by the following factual data. The share of subsoil water supply in annual river drainage represents undoubtedly the natural regulatory characteristics of the river. According to M. I. L'vovich, the share of subsoil water supply of the Oka river up to Orel (F=4570 square kilometers) represents 19 per cent, and up to Murom (F=184,330 square kilometers) it represents 15 per cent of annual drainage. For the Don river, according to the same author, the share of subsoil water supply varies from 39 per cent at Gremyachego (F=60,100 square kilometers), up to 31 per cent at Kazanskiy (F=103,133 square kilometers), and up to 30 per cent at Kalach (F=193,940 square kilometers). Many similar examples could be cited. In all of these cases the size of watershed area does not act as an indicator of the effect wielded by the subterranean water reservoir upon the annual river drainage. On the contrary, for river Terek up to the Kazbek mountain, subsoil water supply constitutes 31 per cent, and up to Amiradzhi-Yurti, 50 per cent: in other words, the subsoil water supply of Terek increases with watershed area, and despite this, according to D. L. Sokolovskiy, the role of such water reservoir can be ignored in the case of mountainous rivers, and must be taken into account for valley rivers.

The crux of the matter is really not in the size of the area, but in the extent over the area of the zonal nature of the basic factors which determine the variability of annual river drainage.

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In 1930 D. L. Sokolovskiy made public the well known formula $C_v = a - 0.063 \log(F+1)$. In this formula, D. L. Sokolovskiy considers quantity a as some climatic parameter. This formula is undoubtedly of empirical nature and has not any theoretical significance; this is particularly easy to verify by tracing the modifications that this formula once underwent while at the same time it seemingly preserved its present form. In D. L. Sokolovskiy's paper in which this formula was first published (1), there is given an isoline chart of the parameter a. On this chart isolines of parameter a increase steadily from north to south, remaining as almost parallel latitudinal circles. Soon thereafter some hydrologists noticed that the use of this formula to determine parameter a leads to profound errors (F. I. Skachkov, V. A. Danovich). As early as the year 1943 D. L. Sokolovskiy recommended the use of a somewhat different formula for the Ural region, such as:

$$C_{vy} = 1.00 - 0.39 \log(M+1) - 0.063 \log(F+1). \qquad (2)$$

In this formula the quantity

$$a = 1.00 - 0.39 \log(M+1) \qquad 3$$

and therefore acquires a climatic-hydrological significance.

In the year 1946 (3) D. L. Sokolovskiy once more reverts to his formula and supplements it with a formula making the first one more exact by taking cognizance of the lakes. In conjunction with this D. L. Sokolovskiy regards parameter a as a geographical parameter and suggests a new isoline chart for this parameter which has very little in common with the initial chart published in 1930. Certain unique features of this chart are worth mentioning. For example, the isoline $a = 0.65$ crosses in its western part the river Dnepr at the city of Kiev, the

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river Volga somewhat south of the 52nd parallel, the river Belaya above the estuary of the river Ufa, the river Chusovaya in its mid-stream, then crosses further the Ural mountain range and enters the bounds of the reservoir of the river Northern Sos'va. It can hardly be seriously argued that the geographical and, even more, climatic significance of parameter a have the same values in the reservoir of Dnepr at Kiev and at the Northern Sos'va river. Along the 55th degree meridian in the upper part of river Vezen', a = 0.55; in the Volga reservoir south of the city of Gor'kiy, a is also equal to 0.55; such examples of unique distribution of the "geographical" parameters are many. Amazing is the extreme variability of the parameter a in western regions, where its isolines form a closed system of lines. Such configuration of isolines of parameter a in this region is due exclusively to the changes of hydrogeological and subsoil conditions in the region, the effect of which in this case cannot be liquidated by introducing into the C_v formula the watershed area value. It is understandable, since in the studied region only the magnitude of the watershed area does not act as indicator of variability in accumulation and expenditure of moisture.

One more factor is noticeable on the chart of parameter a. The maximum values of this parameter at the extreme southwest do not exceed 0.75, while in Table VI of D. L. Sokolovskiy's last paper (3) there are cited values of a for the region considerably in excess of 0.75. How are we to explain these strange properties of isolines of parameter a? Only by the fact that parameter a is not strictly a geographical parameter, but rather a quasi-constant, whose values are determined by the structure of the formula employed by the author. Quasi-constant a includes the effects not only of climatic factors, but of all that is not accounted for by the area effect.

That is why, particularly where the distribution of subsoil water supply loses its latitudinal-zonality character (in Belorussia

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for example), distribution of parameter a also loses these characteristics. As we accumulate new data the chart of parameter a will acquire an increasingly complex nature, and there will be an increase in the number of instances characterized by peculiar, from the geographical viewpoint, features.

According to the opinion of D. L. Sokolovskiy, the chart of parameter a and its use are restricted by certain conditions, depending on the presence or absence of effects of F upon C_v. D. L. Sokolovskiy quite correctly takes those regions for which we can ignore the effect of F, as mountainous regions and such river reservoirs where the role of subsoil water supply is negligible (dry regions of Central Kazakhstan and regions of perennial freshness). Together with this, D. L. Sokolovskiy in the previously mentioned paper recommends the use of a formula containing F* in the same regions, without the slightest embarrassment of this contradiction. For dry regions the area of reservoir F, in my opinion, ceases to act as drainage regulator, only because the variability C_v, for this region, generally speaking, is small, and subsoil waters play a small part in river supply. The basic factor which determines the large values of C_v for rivers of this region is the coefficient of drainage, which attains small values and enters the denominator of my formula. *[Note: "F" stands for "area".]

In mountainous regions the effect of area vanishes in view of the non-zonality of subterranean water and the great influence upon river behavior of the vertical zonality of physico-geographical conditions. In the Far East, for which D. L. Sokolovskiy, following the example of A. I. Chebotarev, believes it possible not to take into account the effect of watershed area, it is necessary to make the following observations. Before everything else, and far from not always, the visible effect of F upon C_v is not absent in the Far East. As, for

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example, in the case of the Amur river at the village Pokrov (F=370,000 square kilometers) C_v = 0.33; at the city of Khabarovsk (F=1,610,000 square kilometers) C_v = 0.22; at the city of Komsomol'sk (F 1,714,000 square kilometers) C_v = 0.21; in other words, for the Amur river C_v decreases as the area increases. It is probable that, by using D. L. Sokolovskiy's formula, it is possible to compute the values of parameter n for different rivers and construct the isoline chart of this parameter, as was done by the author in his paper. The use of this chart for rivers, the data of which areused for its construction, will yield fairly good results. Distribution of the isolines of parameter n in the Far East is of more complex nature than that in the European territory of the USSR.

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*[Note: Hydroelectric Power Plants.]

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