

CLASSIFICATION OF ICELANDIC RIVERS BY THE FLUCTUATION PATTERNS OF RUNOFF

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Abstract This paper describes the effects of the drainage basin characteristics on the fluctuation of river runoff. The drainage basin characteristics influence the amount and rate of water yield and the shape of hydrograph. The drainage basin characteristics are controlled by topographic condition, rock and sediment type, vegetation and land use. Most variable characteristic of Icelandic rivers is the permeability of rock. Iceland is a part of the Mid-Atlantic Ridge and active volcanic zone, that is the highest permeable area, runs across the island. The Tertiary strata which are almost impermeable are exposed at the northwestern and eastern part of Iceland. Icelandic rivers are divided into three groups by the fluctuation pattern of runoff.

“Glacier river”: The amount of runoff varies annually; very large in summer and very little in winter.

“Spring-fed river”: The amount of runoff is very even all the year round and is not affected by rainfall and snowmelt. This type river is mainly found in the highest permeable area of the central zone.

“Direct runoff river”: The fluctuation of runoff is very much dependent on the fluctuations of rainfall and snowmelt, and is very anomalous. This type river is found in the area of the impermeable basaltic rocks.

Key words: Iceland, fluctuation pattern of runoff, auto correlation coefficient, coefficient of variation, glacier river, spring-fed river, direct runoff river

1. Introduction

The drainage basin characteristics influence the amount and rate of water yield and the shape of hydrograph. The fluctuation pattern of river runoff depends on the drainage basin characteristics. The drainage basin characteristics are controlled by topographic condition, rock and sediment type, vegetation and land use. Vegetation of Iceland is very poor. Vegetation and soil conditions of Iceland are uniform through the most part of the whole island. Most variable characteristic of Iceland is permeability of rock. Furthermore the existence of glacier play an important role of the drainage basin characteristics of Icelandic rivers. The Icelandic rivers are grouped in accordance with their geology into the three types (Rist, 1956). If a glacier exists in a watershed, a river is named as “glacier river”. Other rivers are divided into “spring-fed river” and “direct runoff river”.

It is a characteristic of Icelandic geology that there are many spring-fed rivers. Each type river has a typical fluctuation pattern of runoff. The purpose of this paper is the classification of Icelandic rivers by the fluctuation patterns of runoff.

2. Outline of the Hydrogeological Condition of Iceland

Iceland is a part of the Mid-Atlantic Ridge and active volcanic zone runs across the island. Iceland has been built up mostly of lava layers. The Tertiary basalt lava piles have built up the western, northern and eastern parts of Iceland. The oldest lava found in Iceland is distributed in the western fjords (Hjartarson *et al.*, 1980). In these parts of Iceland, the old basalt rocks that have a very low permeability are exposed. Subsurface water hardly exists in the western, northern and eastern parts of Iceland (I.A.H., 1980). On the other hand, there is new lava and tephra in the central zone of Iceland. These lava and tephra are very porous so water permeate easily them. Spatial difference of hydrogeological conditions of Iceland affects the distribution of drainage network. The central zone of Iceland has limited drainage network. Fjords are found in the north-west and eastern parts of Iceland. There are straight rivers with steep channel slope.

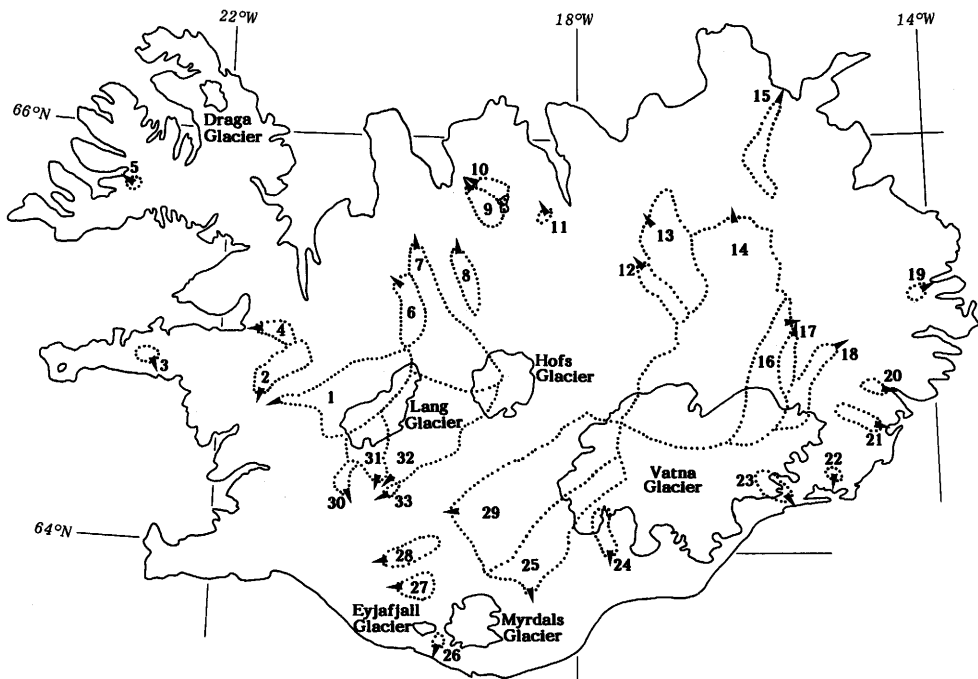


Fig. 1 Location of study watersheds

3. Data of Runoff

The National Energy Authority of Iceland is an organization that supports the development of energy resources. Geologists, geophysicists and geochemists are working in this laboratory. Water Resources Division of this laboratory has been observing the runoff of Icelandic rivers. In order to study the fluctuation of runoff, runoff data of 33 rivers (Fig. 1) are collected at the Water Resources Division of the National Energy Authority of Iceland.

4. Fluctuation Pattern of Runoff

A fluctuation pattern of runoff is influenced by the fluctuations of precipitation. However, there is a case that the difference of the drainage basin characteristics affects largely in the fluctuation pattern of discharge. Icelandic rivers are classified into three types by the hydrogeological condition and the existence of glacier.

First type is the direct runoff river that spreads in the Tertiary basaltic area in the north-west and eastern parts of Iceland. Discharge of the direct runoff river increases

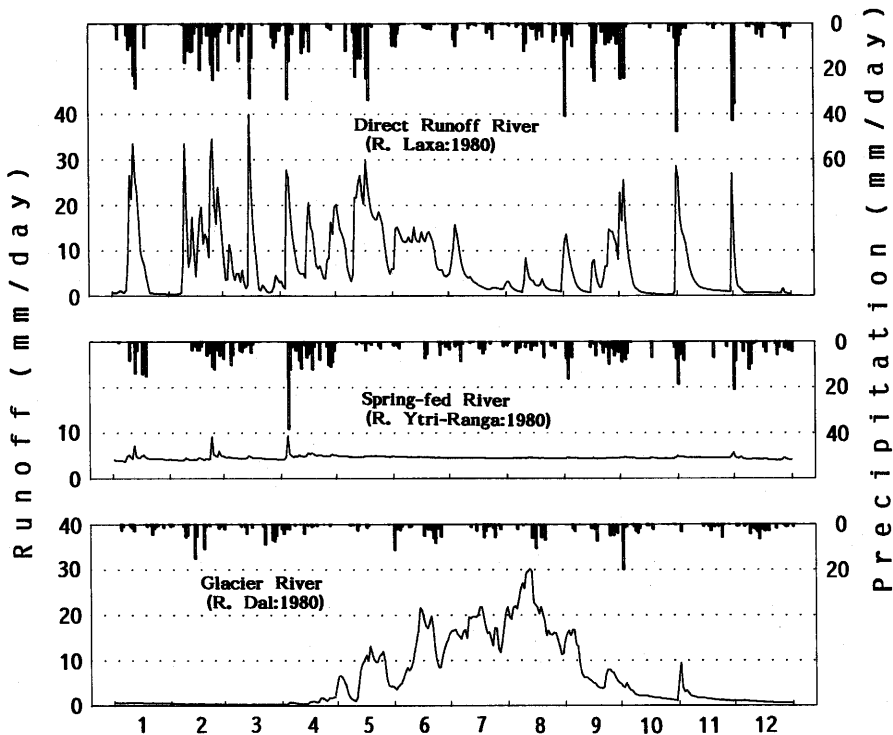


Fig. 2 Hydrographs and hyetographs of selected rivers

and decreases promptly corresponding to a event of rainfall and snowmelt. Also, the water temperature of this type river fluctuates largely in a year. The water temperature is comparatively high during summer. The water surface of this type river is frozen in winter.

Many spring-fed rivers are situated in the central zone where the permeability of rock is very high. Discharge of the spring-fed river has a stable value, and is not affected by rainfall and snowmelt. Discharge and water temperature hardly fluctuate throughout the year. Therefore, the spring-fed rivers are the useful resource of hydro-power plants.

Runoff of the glacier river fed by glacier decreases in winter, and increases as the air temperature increases in spring. The largest runoff of glacier river is observed in summer. The water temperature of glacier river at the tip of glacier is approximately 0°C throughout the year. The glacier river contains a voluminous suspended material which is eroded by a glacier. The color of the water of glacier river is black or gray.

Examples of the hydrograph of the three rivers are shown in Fig. 2 with the hyetograph. The Laxa River (No. 22 in Fig. 2), which flows in the south-eastern basaltic area, is one of the direct runoff rivers. Runoff of the Laxa River is fluctuating corresponding to the events of rainfall. The Ytri-Ranga River (No. 28 in Fig. 2), which flows in the central zone, is one of the spring-fed rivers. Runoff of the Ytri-Ranga River is very even throughout the year and is unaffected by the amount of rainfall. The Dal River (No. 16 in Fig. 2) is fed by the Vatna Glacier. The amount of precipitation is very little in the area

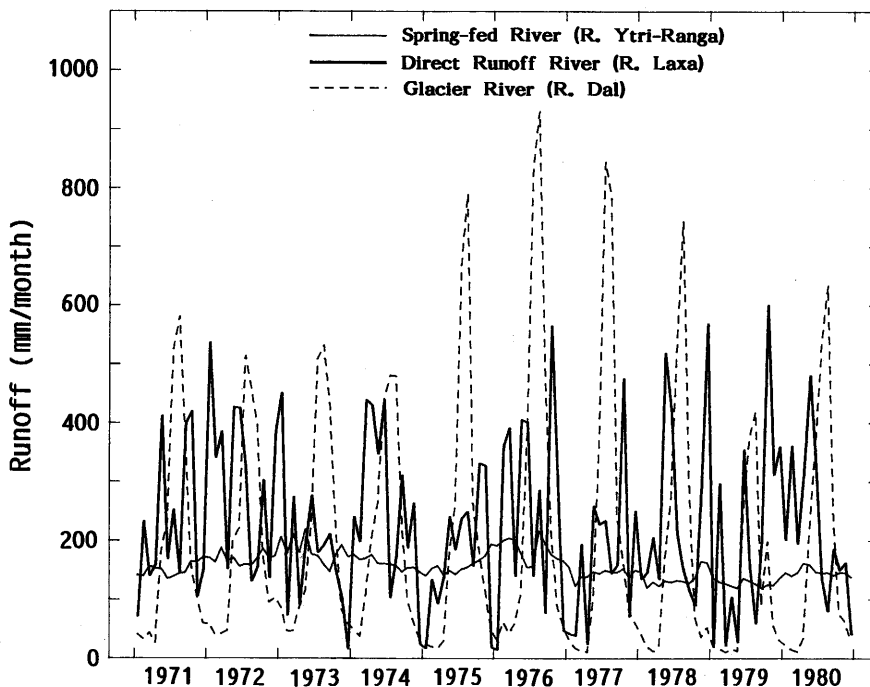


Fig. 3 Fluctuations of monthly runoff of selected rivers

on the north of the Vatna Glacier. Therefore, a large quantity of runoff of the Dal River is fed by the Vatna Glacier. The amount of runoff is very large in summer and very little in winter. The fluctuation of runoff presents the typical pattern of hydrograph. The hydrographs of many rivers are illustrated by the coexistence of each type.

5. Classification of Rivers by the Fluctuation Patterns of Runoff

The fluctuation of the amount of runoff is clearly reflected by the drainage basin characteristics. The fluctuation of the monthly runoff is examined quantitatively.

The amounts of monthly runoff from 1971 to 1980 of the same rivers of Fig. 2 are shown in Fig. 3. The amount of monthly runoff of the spring-fed river fluctuates very small in comparison with other types. The glacier river shows a regular seasonally variation. On the other hand, the direct runoff river shows a wide variation, and a periodicity of variation is not recognized. Therefore, it is suggested that the Icelandic rivers are classified by the range and regularity of runoff.

Auto correlation coefficient indicates the regularity of variation. Auto correlation coefficient of the monthly runoff is calculated for each type of river. Correlogram of each river type is shown in Fig. 4. It is confirmed that the runoff of the glacier river fluctuates with a cycle of 12 months. The auto correlation coefficient of the glacier river (Dal River) is 0.89 at 12 months lag. A periodicity of the direct runoff river is not recognized. The fluctuation of runoff of the direct runoff river is extremely random. A periodicity of the spring-fed river is not recognized. The variation of runoff of the spring-fed river shows a strong durability.

A periodicity of the runoff can be examined by correlograms. The correlograms of 33 rivers are drawn, and the auto correlation coefficient of 12 months lag is adopted as a measure of a periodicity of runoff. The coefficient of variation of the monthly runoff is

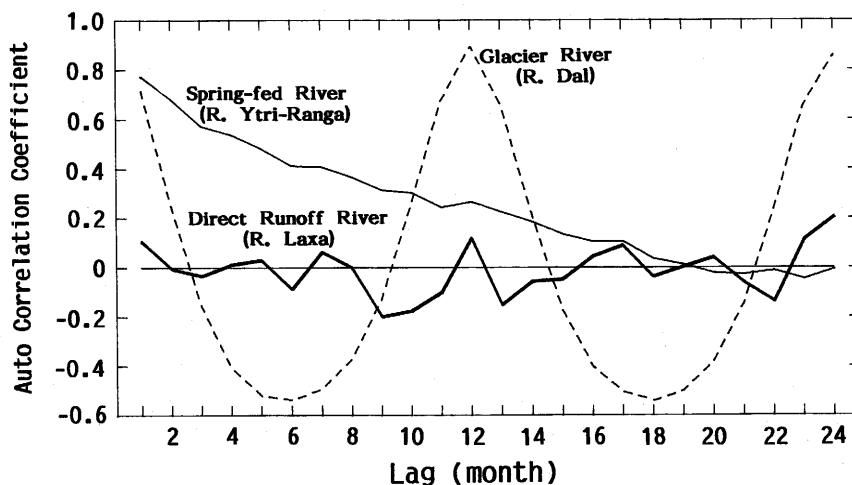


Fig. 4 Correlograms of selected rivers

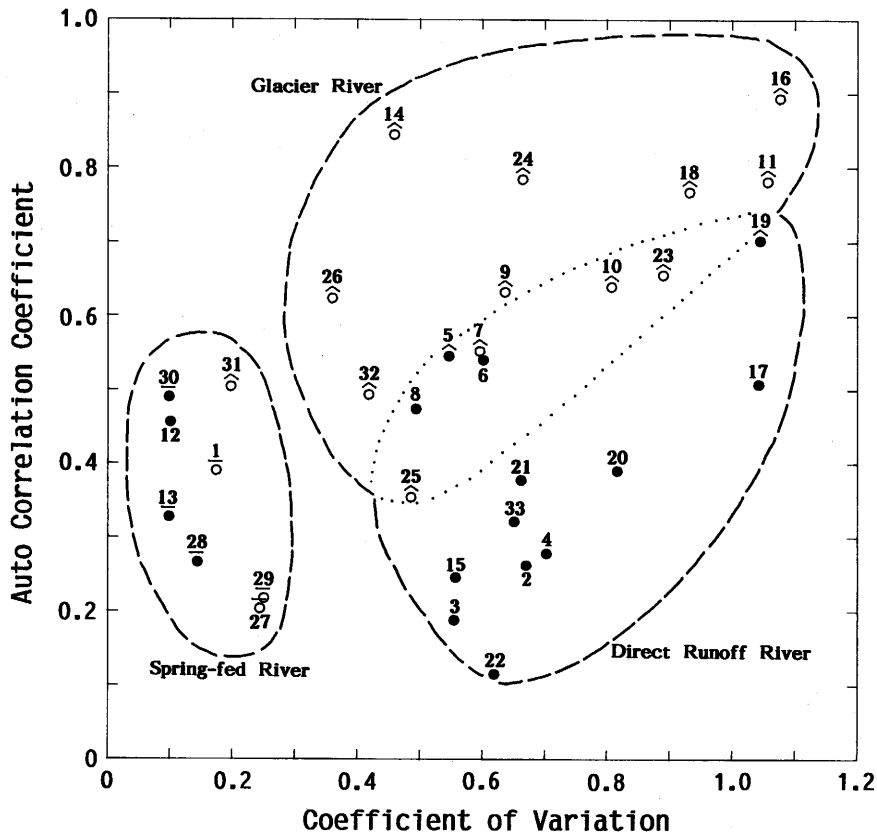


Fig. 5 Relation between auto correlation coefficient of 12 months lag and correlation of variation of the monthly runoff
 ○: glacier exists in the watershed, ●: glacier nonexists in the watershed,
 ■: correlogram shows one year cycle, -: correlogram shows durability

adopted as a measure of a range of fluctuation. The relationship between auto correlation coefficient and coefficient of variation is indicated in Fig. 5. The rivers are plotted in the lower-left side of Fig. 5 show a little variation of the monthly runoff, and a periodicity of runoff is not admitted in this river. The rivers plotted in the upper-right side of Fig. 5 show a wide range of fluctuation of the monthly runoff, and one year cycle of runoff is clear in these rivers. The difference between coefficient of variation of the glacier river and that of the direct runoff river is not recognized in Fig. 5. However, the auto correlation coefficient of the glacier river is larger than that of the direct runoff river. Furthermore, a correlogram of the glacier river shows a clear one year cycle. Eystri-Ranga River (No. 27 in Fig. 5) and Tungnaa River (No. 29 in Fig. 5) have glaciers in each watershed (Tindfjalla Glacier and Vatna Glacier). But the area of glacier is very small in these watersheds, and the two rivers flow in the permeable area of the central zone. So that, these two rivers are considered to have a characteristic of the spring-fed river. Laxa River (No. 22 in Fig. 5), which is typical of the direct runoff river, has a lower

auto correlation coefficient. Dal River (No. 16 in Fig. 5), a typical glacier river has high auto correlation coefficient and a high coefficient of variation. The Icelandic river can be classified into the following types from Fig. 5 that shows the relation between auto correlation coefficient of 12 months lag and coefficient of variation.

“Spring-fed river”: The coefficient of variation is below 0.3. The range of fluctuation of the monthly runoff is small and the durability of that is recognized. All this type river are found in the central zone.

“Glacier river”: The difference between coefficient of variation of the glacier river and that of the direct runoff river is not distinguished. The auto correlation coefficient of 12 months lag of the glacier river is larger than that of the direct runoff river. A clear periodicity of runoff is recognized.

“Direct runoff river”: The coefficient of variation of this river is comparatively large. The variation of runoff is very anomalous.

The separation of the spring-fed river from others is easily possible from the value of a coefficient of variation. The separation of the glacier river from the direct runoff river is not possible with only a coefficient of variation. However, a periodicity of runoff allows the separation of the glacier river from the direct runoff river easily.

6. Conclusion

The effects of the drainage basin characteristics on the fluctuation of river runoff are examined. The geological condition and the glacier affect the fluctuation pattern of runoff.

Icelandic rivers are divided into three groups by the fluctuation pattern of runoff.

“Glacier river”: The amount of runoff varies seasonally; very large in summer and very little in winter.

“Spring-fed river”: The amount of runoff is even all the year round and unaffected by rainfall and snowmelt. This type river is mainly found in the central zone composed of the highest permeable rocks.

“Direct runoff river”: The fluctuation of runoff is dependent on the fluctuations of rainfall and snowmelt. This fluctuation is very anomalous and is largely. This type river is found in the area of the impermeable basaltic rocks.

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