No. B-11.2 Impact of Climate Change on Hydrologic Cycles in Cold Regions

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Total Budget for 1990-1992 13,210,000 Yen

Abstract

First, we have collected and investigated the meteorological data such as temperature and precipitation amounts for a past hundred years in Hokkaido. The analyzed results show that few snowfall and snowpack amounts appear to be indicated in a recent couple of years. Then, an attempt was made to develop the snowmelt runoff model based on the remote sensing information in order to investgate the current and future snowmelt runoff situations as well as water resource managements in the cold regions. An attempt was also made to develop the long and short terms runoff model in order to evaluate the annual hydrological cycle in a catchment area. The effect of climate changes on runoff patterns is investigated by the present model. The results show that the hydrological responses are more sensitive to temperature changes than to precipitation changes in Hokkaido because the hydrologic cycle highly depends on the snowmelt pattern.

Key Words Remote sensing, Degree-Day method, Snowpack amount, Snowmelt runoff amount, Long and short terms runoff model

1. Introduction

There are world-wide concerns on global environmental issue; increasing concentration of greenhouse gases are expected to cause a significant warming of global climate in the next century. Although estimates of the changes in precipitation patterns vary considerably from one *GCM* to another, all *GCMs* show shorter snowfall and snowmelt seasons due to increases in average temperatures. The change in snowpack conditions, in turn, leads to the earlier and significant increase of evaporation from bare soils which is, in turn, responsible for much of the summer soil-moisture effects. Similar alterations of snowfall and snowmelt conditions exert influences on the annual runoff pattern.

2. Research Objective

The current study is concerned with identification, analysis and evaluation of possible changes of annual hydrologic responses anticipated to be caused by climate change. Outcomes of the study will be used to determine how reliable water supply strategy could be incorporated formally in a within-year reservoir operation in cold regions.

3. Research Method

We have investigated the meteorological data such as temperature and precipitation amounts for a past hundred years in Hokkaido. The purpose of this investigation was to investigate past climate change.

An attempt was made to estimete the snowpack amount based on the remote sensing information in order to investgate the current and future snowmelt runoff situations as well as water resource managements in the cold regions. The model is able to estimate the snowpack amount from the change in the snow covered area that is derived through the aerial photogrammetry.

Special attention is directed to the investigation of the various effects on the global warming using this model. The Jozankei dam catchment (Fig.1) is selected as the study area for the investigation of snowmelt runoff. In this area, the simple model is applied to estimate the snowmelt amount resulting from use of Degree-Day factor, and the autoregression (AR) model is applied to characterize the runoff due to snowmelt. We apply the senario of global warming calculated by the *GCM* to the evaluation of snowmelt runoff pattern.

An attempt was made to develop the long and short terms runoff model (Fig.2) in order to evaluate the annual hydrological cycle in a catchment area. The effect of climate changes on runoff patterns is investigated by the present model.

Fig.1 Jozankei dam catchment area

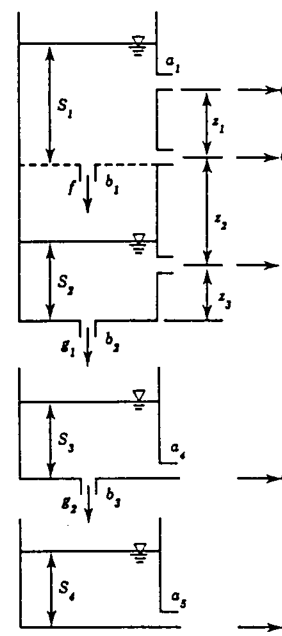

Fig.2 Schematic figure of the long and short terms runoff model

4. Result and Discussion

The climate change is investigated by the past meteorological data. Figure 3 shows the temperature record for the past 100 years in Suttsu. It shows a general increase of 0.4°C in this period. According to the precipitation record, the period between 1920 and 1970 had a relatively high amount of precipitation but since 1970 there has been a general decrease in precipitation. However, there has been an increase in the frequency and magnitude of heavy precipitation events. Ten year periods were examined in order to determine the relationship between temperature and precipitation. The period from 1904-1913 was chosen as the coldest decade, and two ten year periods, 1955-1964 and 1982-1991, were chosen as the warmest decades. Number of day of heavy rainfall in the cold decade (1904-1913) is related to that of the two warm decades (1955-1964, 1982-1991) for various locations in Hokkaido. There are more days of heavy rainfall in the warm periods than in the cold period. Figure 4 is a graph showing the amount of precipitation on days having annual maximum value for the cold versus warm periods. There is in general a greater magnitude of heavy precipitation events in the warmer periods than in the cold periods. It may be expected that total amount of precipitation will decrease, while the frequency and magnitude of heavy precipitation will increase even in cold and snowy regions as a result of global warming.

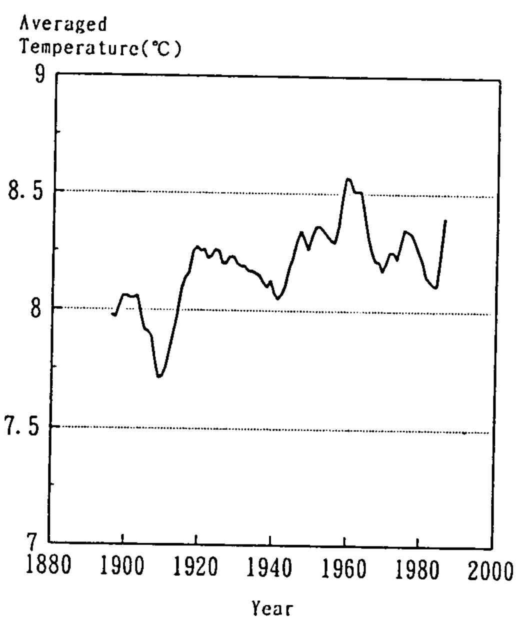

Fig.3 Temperature change in Suttsu

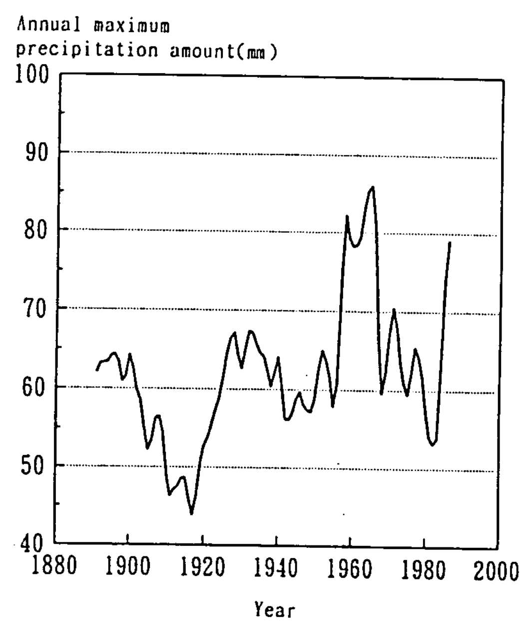

Fig.4 Change of annual maximum precipitation amount

The snowpack amount is estimated by the Degree-Day Method, and using the remote sensing information. The snowmelt amount is then used along with an estimation of base flow and rainfall to reproduce discharge by using an autoregression (AR) method. Figure 5 shows a comparison of the calculated versus observed total runoff amount during a snowmelt season. The result shows the methodology based on the remote sensing is able to estimate the snowpack amount so that the water balance can be evaluated in a catchment area.

Accordingly, the observed and calculated hydrographs due to snowmelt are shown in Fig.6. The graph shows that there is a high degree of correspondence between the observed and calculated discharges in the snowmelt season.

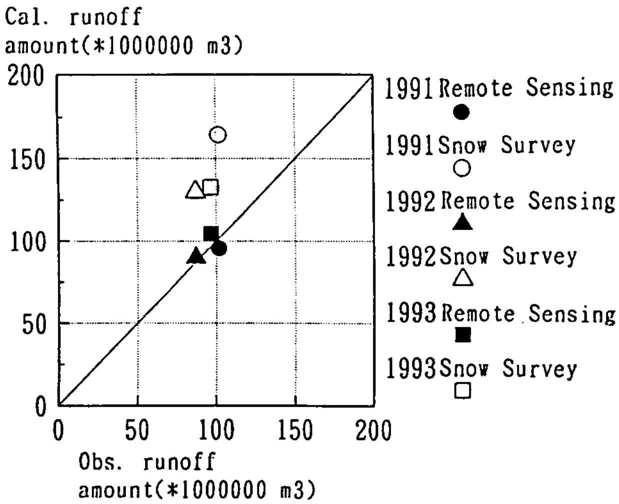

Fig.5 Observed and calculated total runoff amount during a snowmelt season

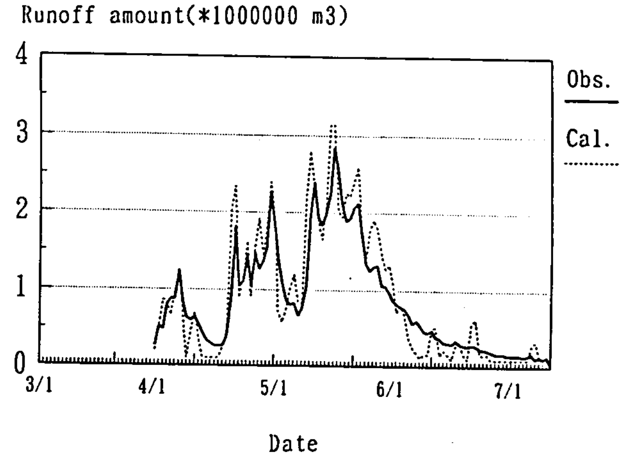

Fig.6 Observed and calculated hydrographs due to snowmelt

An attempt was made to develop the long and short terms runoff model in order to evaluate the annual hydrological cycle in a catchment area. The effect of climate changes on runoff patterns is investigated by the present model. Model parameters are determined by the Powell method. Estimated snowpack amount and snowmelt amount are used for the annual runoff model. Figure 7 shows observed and calculated hydrographs.

Finally, the following six scenarios were simulated using the runoff model.

1. temperature increase 2°C, precipitation constant
2. temperature increase 4°C, precipitation constant
3. temperature increase 2°C, precipitation reduced 10%
4. temperature increase 4°C, precipitation reduced 10%
5. temperature increase 2°C, precipitation increased 10%
6. temperature increase 4°C, precipitation increased 10%

Figure 8 shows that the primary change due to global warming is a shift in the peak of the snowmelt season from May to April. Achange in the amount of precipitation appears to have little impact on the overall snowmelt runoff pattern. It is the temperature increase which gives rise to a change in the timing of the snowmelt season. The results show, in general, that the hydrological responses are more sensitive to temperature changes than to precipitation changes in Hokkaido because the hydrologiccycle highly depends on the snowmelt pattern.

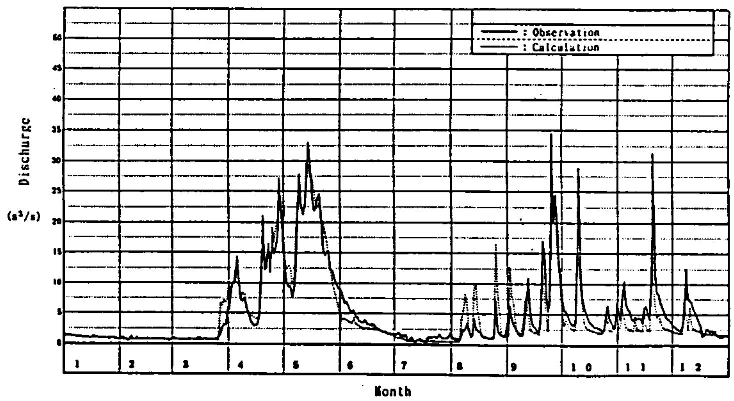

Fig.7 Observed and calculated annual runoff pattern

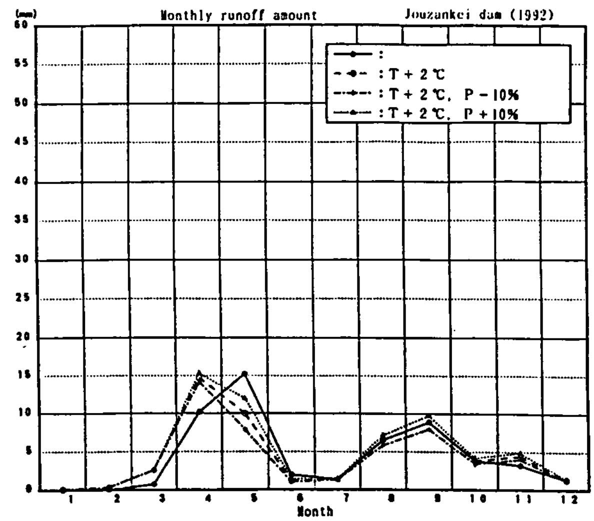

Fig.8 Change of annual runoff pattern due to global warming

5. Conclusions

(1)The temperature increases in the past 100 years even in Hokkaido. (2)Total precipitation amount in a year recently decreases, while the frequency and magnitude of heavy precipitation events increase. (3)The snowpack amount can be estimated by the Degree-Day method, and using the remote sensing information. The methodology based on the remote sensing is able to estimate the snowpack amount so that the water balance can be evaluated in a catchment area. (4)The Degree-Day method is applied to estimate the snowmelt amount, and the autoregression (AR) model is applied to characterize the runoff due to snowmelt. Using the estimated snowpack and snowmelt amount, annual runoff pattern is reproduced by the long and short terms runoff model. (5)We apply the scenario of global warming to the evaluation of snowmelt runoff pattern as well as annual one. The primary change due to global warming is a shift in the peak of the snowmelt runoff amount from May to April. The hydrological responses are more sensitive to temperature changes than to precipitation changes in Hokkaido because the hydrologiccycle highly depends on the snowmelt pattern.

6. References

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