Analysis of long-term water balance of the Yellow River basin using the hydrological and water resources model -Impacts of the human activities-

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Abstract

We attempt to develop a hydrological and water resources model and procedures to clarify the influence of human activities on the river runoff of the Yellow River basin. Although there are various human activities that affect the river runoff, we focused on the following three factors: (1) reservoir operation, (2) irrigation water intake from the river channels and (3) land use change during the period from 1960 to 2000.

1. Introduction

In order to analyze the hydrological processes of the large river basin such as the Yellow River, it is necessary to take into consideration not only natural factors but also artificial factors. In particular, the operation of reservoir and water intake for the irrigation is two major human activities, which may have profound impact on hydrological cycle. Moreover, the artificial land-use change is another factor as it changes the amount of water losses from land surface by the evapotranspiration. In this study, we analyzed long-term (1960-2000) water balances of the Yellow River basin using high resolution (0.1 degree) hydrological and water resources model considering not only natural factors (such as climate changes) but also above all artificial factors.

2. Study area and outline of the model

The Yellow River is the second-largest (also the longest) river basin in China. It originates from the Tibetan Plateau, wanders through the northern semiarid region, crosses the loess plateau, passes through the eastern (North China) plain, and finally discharges into the Bohai Sea. In general, the basin is divided into the following four sub-basins: (1) Source area (upstream of Tangnaihai gauge), (2) Upper reach (between Tangnaihai and Toudaoguai gauges), (3) Middle reach (between Toudaoguai and Huayuankou gauges) and (4) Lower reach (downstream of Huayuankou gauge). However, herein we separated the upper reach into two regions by Lanzhou gauge to detect the influences of reservoir operations and irrigation water intake respectively. For the middle reach, we focused on the water balance at Sanmenxia gauge in this issue.

The model used in this study is based on the SVAT-HYCY model developed by Ma and Fukushima (2002). The original model is composed of three components: one-dimensional SVAT model, runoff formation model, and river routine model (Ma et al., 2005). In this study, we modified the procedure of actual evapotranspiration estimation. The potential evaporation is calculated according to the approach defined by Xu et al. (2005). Actual evapotranspiration is then regarded as a function of potential evapotranspiration, LAI and soil moisture content, which was proposed by Kondo (1994). The land use type of the basin was divided into five types (Type1: Barren and Urban; Type2: Grass and Shrub; Type3: Forest; Type4: Irrigated and Type5: Water and

Snow) based on the dataset classified by Matsuoka et al., (2005).

3. Results and discussion

3.1. Tangnaihai

According to the remote sensing data, more than 90 % of the land surface is covered by the grass in the upstream of Tangnaihai and there are no large dams and irrigation areas. Therefore, the discharge pattern at Tangnaihai gauge is mainly influenced by the natural factors. Figure 1 shows the monthly discharge at Tangnaihai gauge from 1960 to 2000, where there is good agreement between observed discharge and simulated one.

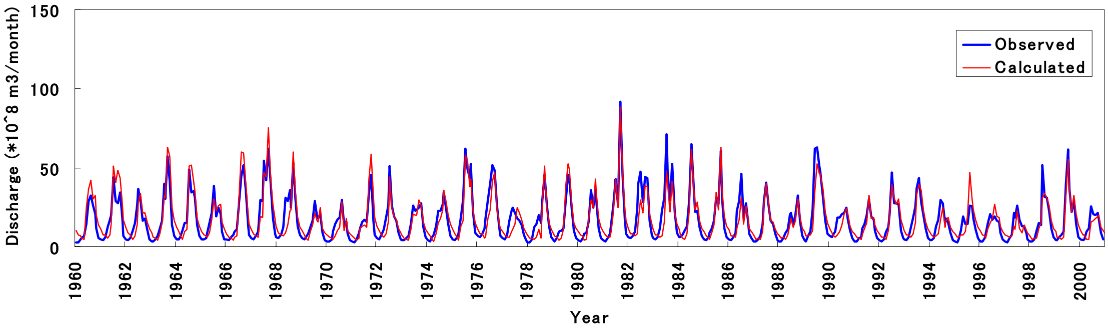

Figure 1 Monthly discharge at Tangnaihai gauge from 1960 to 2000.

3.2. Lanzhou

There are two large dams (Liujiaxia dam and Longyangxia dam) in the upstream of the Yellow River basin. Therefore, the observed discharge shows different seasonal change pattern to the natural discharge. According to the condition of the reservoir operation by the dams, we divided the period of analysis as follows: (1) from 1960 to 1968, no large dams existed in this period; (2) from 1969 to 1986, the river flow had been regulated lightly by the Liujiaxia dam; and (3) from 1987 to 2000, the river flow had been controlled strongly by the Longyangxia dam together with the Liujiaxia dam. Then, we extracted the reference seasonal discharge pattern (average monthly discharge pattern using the observed data except for the flood period) and applied it to the reservoir operation model developed by Sato et al. (2004). Figure 2 shows the performance of our model applied to the monthly discharge of Lanzhou gauge. This result suggests that our model can predict the various artificial controls by the dams (i.e. the peak flood mitigation or stable water supply during heavy water demand season) satisfactory.

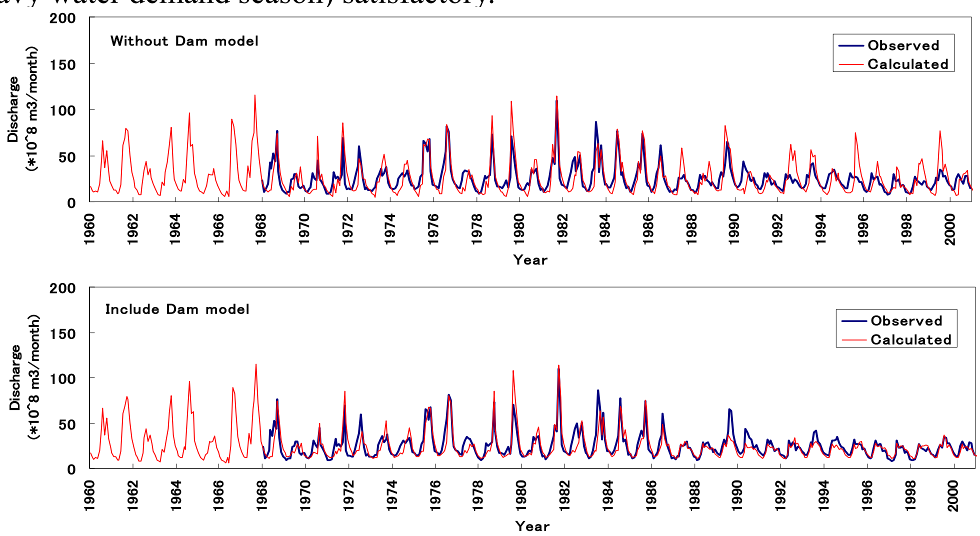

Figure 2 Comparison of monthly discharge at Lanzhou from 1960 to 2000 calculated by without dam model and include dam model.

3.3. Toudaoguai

Between Lanzhou and Toudaoguai, there are large irrigation areas include the Qingtonxia and Hetao irrigation districts, which consumes great amount of water from the river channel. According to the differences of observed discharge between Lanzhou and Toudaoguai (Lanz – Toud), it shows that almost 10 billions m^3 of river water lost in this area (Figure 3(d)). In this study, we analyzed the water balances of non irrigated area and irrigated area separately. In the irrigated area, the discharge from irrigated area during irrigation period was calculated by P (Gross Precipitation) – Ep (Potential Evaporation) and P – Ea (Actual Evapotranspiration) for the non irrigation period. In our irrigation model, the negative discharge is corresponding to the water intake from river channel. The modeling results have shown that there is little discharge from non irrigated areas due to the dry climate condition, while the amount of actual evapotranspiration is almost the same to gross precipitation amount (Figure 3(a)). In the irrigated area, the amount of Ep exceeded more than three times of P. It suggests that in order to satisfy the water demand for the irrigation, it is necessary to intake more than 10 billion m^3 of water from the river channels continuously. Consequently, the total discharge from this area (Figre 3 (c)) became almost same amount of "Lanz - Toud" in Figure 3(d). We also found that the "Lanz - Toud" does not changed significantly during the past 40 years.

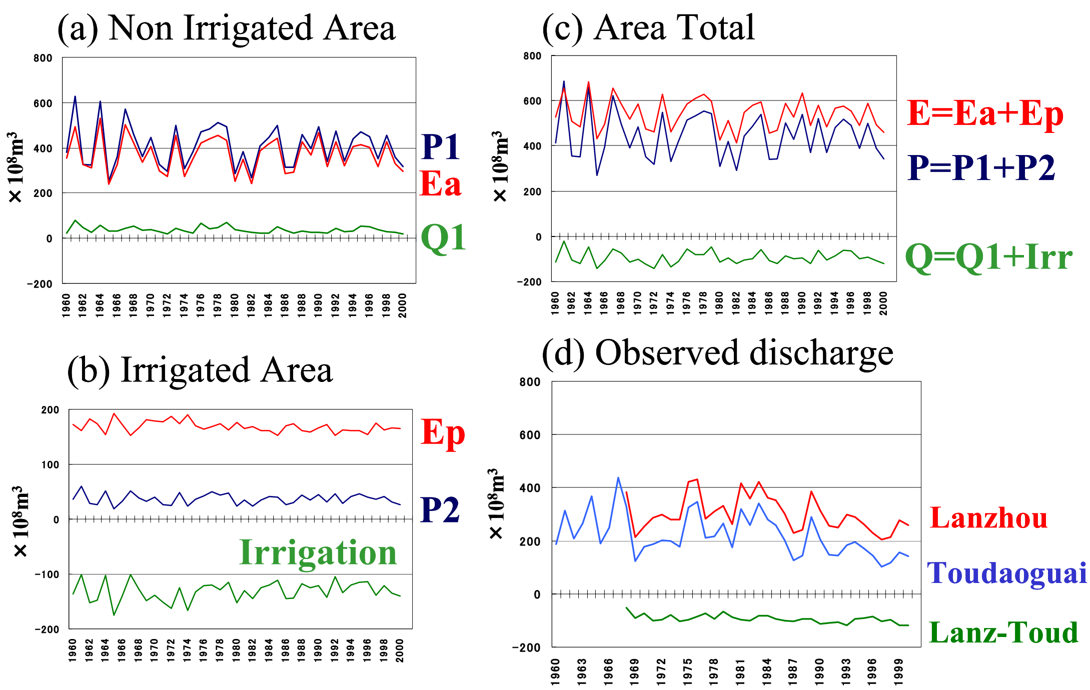

Figure 3 Water balance of the Irrigated area between Lanzhou and Toudaoguai.

3.4. Sanmenxia

In the middle reach, the calculated discharge from non irrigated area was also quite small (Figure 4 (a), which implies that most of the rain water was consumed within this middle reach.). It is correspondent to recent drying up of small tributaries in the middle reach. The estimated water loss by the irrigation was almost constant (Figure 4(b)). However, the estimated total discharge of Sanmenxia does not show a good agreement with observed values. In particular, it overestimates evapotranspiration in the 1960's to early 1970's, which has call for research efforts on long-term land use change.

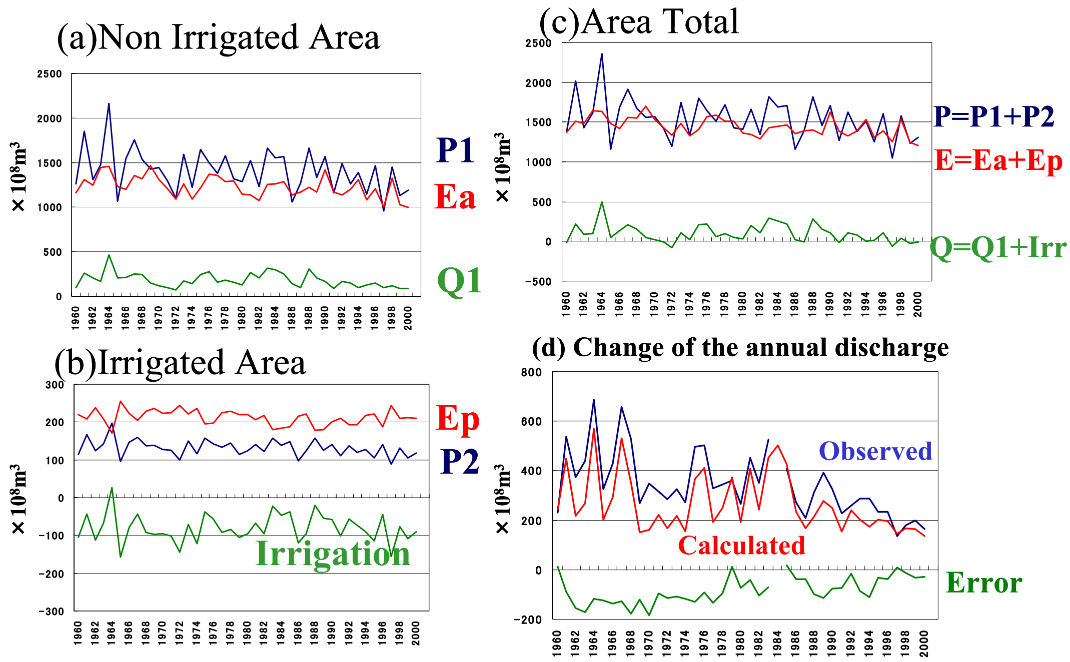

Figure 4 Water balance of the Middle reach of the Yellow River basin.

4. Conclusions

A modified version of hydrological and water resources model was developed and applied to the analysis of long-term water balances in the Yellow River basin. Modeling results have shown good agreement between observed discharge and simulated one not only in the source area (nearly natural status) but also upper reaches (under impacts of artificial factors such as dam operations and irrigation water intakes). However, it is still a challenge in modeling water cycle in the middle reach for its highly complexity. Further study is needed to improve our model to evaluate the influence of the long-term land use change.

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