RUNOFF PROPERTIES OF THE AMUR RIVER AND THE CONSTRUCTION OF THE HYDROLOGICAL MODEL INCORPORATING DISSOLVED IRON TRANSPORT

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INTRODUCTION

The Amur River is one of the largest trans-boundary river which runs through the boundary between China and Russia. The catchment area of the river is 2,050,057km^2 which is the nineth largest river in the world and the total length of the river is 4,350km. Thus, huge amount of fresh water is supplied by the Amur river to the Sea of Okhotsk (Ducklow et al., 2003). The Sea of Okhotsk is one of the most biologically productive regions in the world, and it supports high fisheries production. Recent studies show that dissolved iron plays an important role to maintain the biological productivity of the Sea of Okhotsk, and we suppose that one of the possible sources of dissoloved iron is fresh water from the Amur river. Iron is an essential nutrient not only for the biological productivity of the Sea of Okhotsk but also for most biota. However, it is not well understood that how dissolved iron is produced and transported through the terrestial ecosystem. One of the our goals in the project is to clarify the mechanism of producing dissoloved iron in the terresial ecosystem and to construct a hydrological model which incorporate the mechanism of dissolved iron production. In this report, I discuss some hydrological properties of the amur river basin, and figure out the basic structure of the hydrolgoical model incorporating dissolved iron production.

1. GEOGRAPHICAL PROPERTIES OF THE AMUR RIVER BASIN

The catchment area of the Amur river is 2,050,057km^2, and the total length of the river is 4,350km which is the seventh longest river in the world. As shown in Figure1, average elevation and maximum elevation of basin are 545m and 2,641m respectively. More than 50 percent of the land are located under the elevation of 500m. Main tributaries of the basin are Songhua (Chinese part),Argun, Zeya,Silka, Ussuri. Each basin area is 53,5232km^2, 29,8361km^2, 23,3311km^2, 20,2924km^2, 19,5101km^2. In addition, average river bed slope

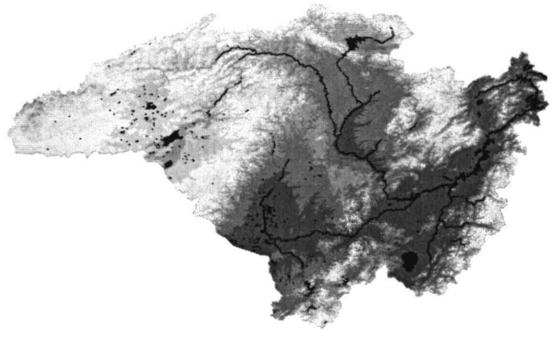

Figure1. Outline of the Amur River Basin

from the river mouth to Khabarovsk calculated from DEM data which was construced by SRTM (Shuttle Radar Tomography Mission) is about 1/25,000. Compared to the other large continental river, it is cleared that the Amur river basin is very flat.

Figure 2 shows the landuse composition ratio of the basin. Most dominant land use is forest which consists of mixed forest, deciduous forest, and coniferous forest. Next, dry land occupies major part of the landuse. Most part of the dryland locates in the Songhua river basin. Wetland consists about 7 % of the total basin area. And most part of it locates along the main course of the Amur river. From on-site investigation through this year and last year, Forest and wetland have a possibility of producing dissolved iron. Figure 3 is a plot of iron concentraton of main tributaries against the forest and wetland mixed with forest. It shows that dissolved iron concentration from forest is slightly lower than that from wetland mixed with forest.

From the view point of constructing the hydrological model, if we can find some relation between topographical property of catchments and iron concentration of the river water, we can incorporate such relationship into hydrological model (Shibata et al., 2004). Thus, here, we investigate the relationships between topographic index and annual mean dissolved iron concentration of the main tributaries which were measured in 2002 and Gassi Lake catchment. Topographic index is defined as follows (Beven and Kirkby, 1979).

$$a/\tan\beta \qquad (1)$$

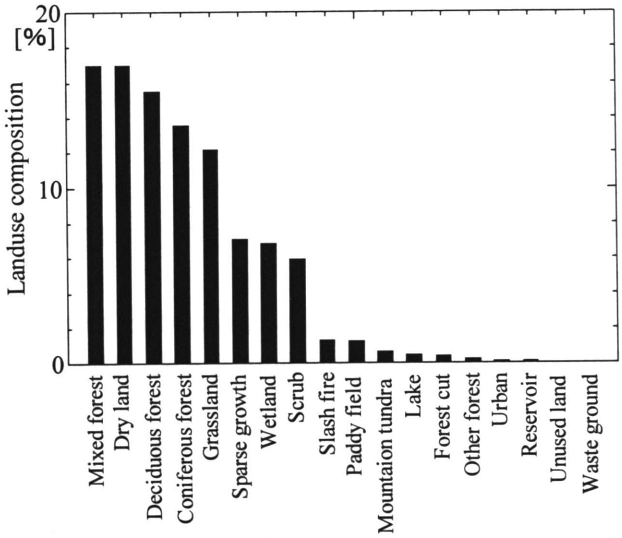

Figure 2. Landuse composition of the amur river basin

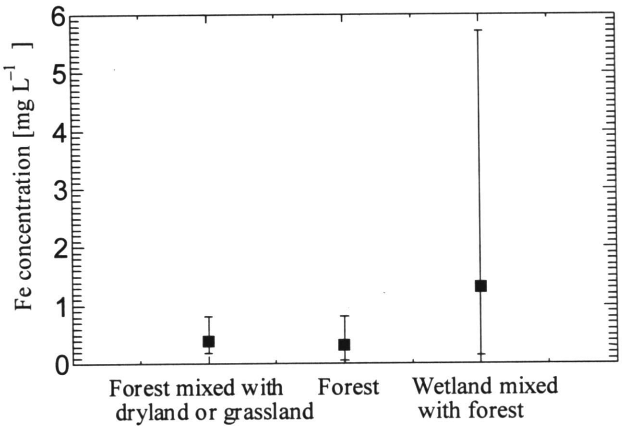

Figure 3. Fe concentration range plotted against landuse pattern of catchment area

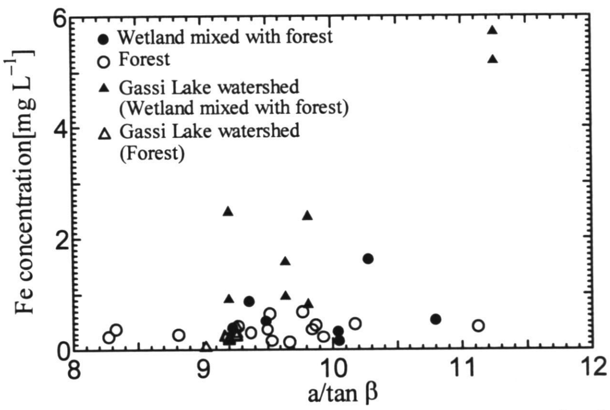

Figure 4. Fe concentration plotted against mean a/tanb of each catchment

Here, a: catchment area per unit contour length[L^2], β:most gradient slope of the each grid[-].

Figure 4 is a plot of annual mean dissolved iron concentration of the main tributaries against the mean topographic indicies of a catchment area of the point where dissolved iron concentration was measured. It can not to be found distinct relationship between topographic indicies and iron concentration of each tributaries. One main reason is supposed to be that hydraulic conductivity and soil types of each catchment is also important effect on the productivity of the dissolved iron. However, it can be said that productivity of dissoloved iron from forest is constantly below 1.0mg L^{-1} in spite of the values of $a/\tan\beta$. On the other hand, catchments which include wetland have a tendency to produce higher dissoloved iron concentration than forest in general.

2. DISCHARGE DATA AND WATER BUDGET

One of goals of our project is to assess the impact of human activities on the productivity of dissolved iron. Within the Amur river basin, many wetland in China have converted to the dry land and paddy fields especially in the past 20 years. Another possible impact of human activity was the construction of dam mainly for electricity in the upper part of the Zeya river in 1978. Thus, to evaluate impacts of these activities on the hydrological properties and dissolved iron productivity, relatively long term meteorological data is needed.

Figure 5 shows the annual precipitation, evapo-transpiration, discharge at the Bogorodskoye and calculated discharge by substituting evapo-transpiration amount from precipitation amount during the period from 1948 to 2002. Annual precipitation and evapo-transpiration amount of the basin is constructed from the National Centers for Environmental Prediction (NCEP) / National Centers for Atmospheric Research (NCAR) Reanalysis1 data sets (http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.html). Annual discharge data is from

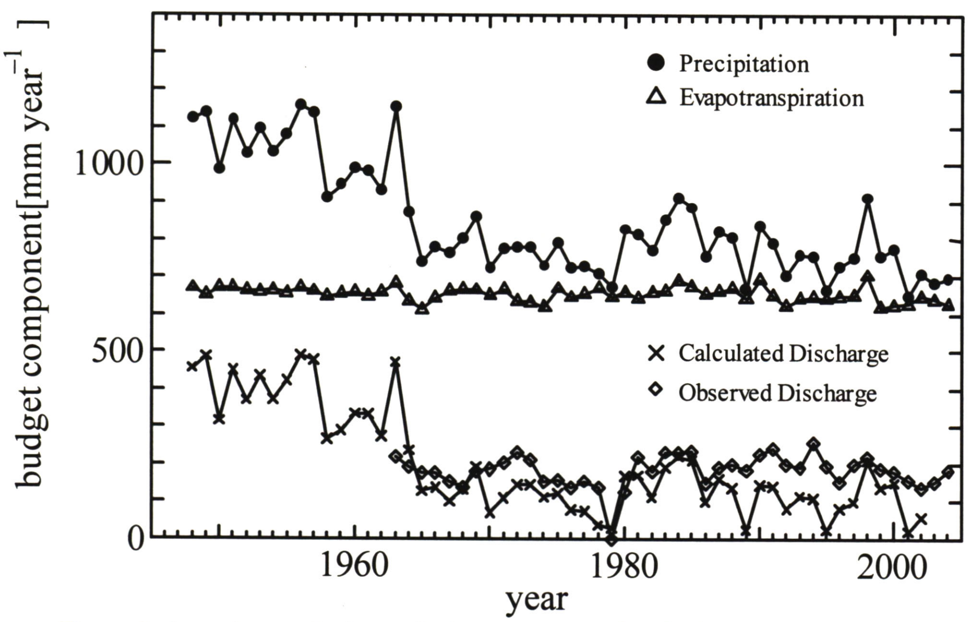

Figure 5. Annual water budget calculation compared with observed discharge data

Global Runoff Data Center (GRDC, http://grdc.bafg.de/servlet/is/987/). Annual trend of calculated discharge is roughly corresponding to the observed discharge. However, there is non-negligible discrepancy between measured discharge data and calculated discharge amount especially during the period from year 1990 to 2000. When we use these data as an input to the hydrological model, some modification to the precipitation and evapo-transpiration should be done.

For the purpose of detecting the evidence of impact of human activities on river discharges, I attempted to detect the drastic change of discharge regime. To do this, select any year within the annual discharge data set of interest, and the data set are split into two data sets: one is before the selected year and the other is after the selected year. And the significance of difference between two annual discharge data sets using Student's t-statistics (Oki, 1999, Press et al., 1993) was evaluated. The t-statistics for the difference of variance of two data sets (here, we define one data set as $x_i(i=1,N_x)$, and the other data set as $y_i(i=N_y)$) is defined as follows.

$$t = \frac{\bar{x} - \bar{y}}{\left[\sigma(x)^2/N_x - \sigma(y)^2/N_y\right]^{1/2}} \quad (2)$$

Here, $\bar{x}$:mean of x_i, $\bar{y}$:mean of y_i, $\sigma(x)$:variance of x_i, and $\sigma(y)$: variance of y_i.

Figure 6 shows the significance of the t-statistic for the observed discharge at the Khabarovsk. Significance level is drastically decrease around early 1960's, but it does not go down below the level 0.01. Although it is difficult to identify the reasons, there might some important changes occured during early 1960's. If an assumption that there was no significant antholopogenic impact in the Russian part during early 1960's is correct, there is a possibility that some anthlopogenic impact has occured along the Songhua river. At least, the impact of dam construction on the discharge regime of middle and lower part of the Amur river is not

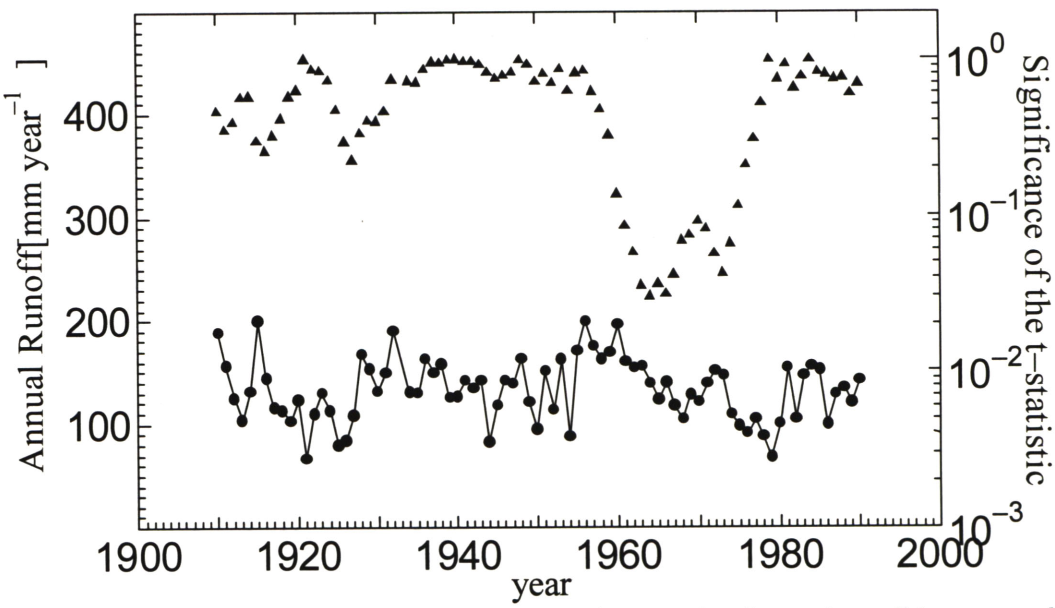

Figure 6. Student's t-statistic for the differecne between the two splitted annual runoff data sets at the Khabarovsk observation station

detected. However we can not reject a possibility of the dam impact on the discharge regime and dissloved iron productivity along the Zeya river basin, because Khabarovsk is about 1,000km downstream of the confluent point of the Zeya river and the Amur river. Thus, we should examine whether significant discharge change has occured along the Zeya river after the construction of dam.

3. CONSTRUCTION OF HYDROLOGICAL MODEL INCORPORATING DISSOLVED IRON TRANSPORT

As shown in Figure 7, hydrological model which incorporates the dissolved iron production consists of two steps according to the scale difference. First, using GETFLOWS (Tosaka et al. 2000) which is one of the distributed-physically based models, we construct a model which can simulate discharge regime and dissolved iron concentration simultaneously in the relatively small scale basin. Free ferrous iron is produced through continuous redox processes in soils. Though, redox processes are complex biogeochemical process, for *N* types of chemical species, *N* convection-dispersion system equations can be formulated in general. However, if we can identify *N* types of chemical species related to the free ferrous iron and dissolved iron production, we can not identify all parameters. Thus, in our model, we only consider the exchange between dissolved iron and iron absorbed to the solid phase in soils. Through the optimization process, we identify parameters which can describe dissolved iron production from each landuse such as wetland, forest, paddy fields, and dryland. This step is now under progress. Based on parameters for each landuse which are identified by the first step, hydrological model for the whole catchment scale is going to be constructed.

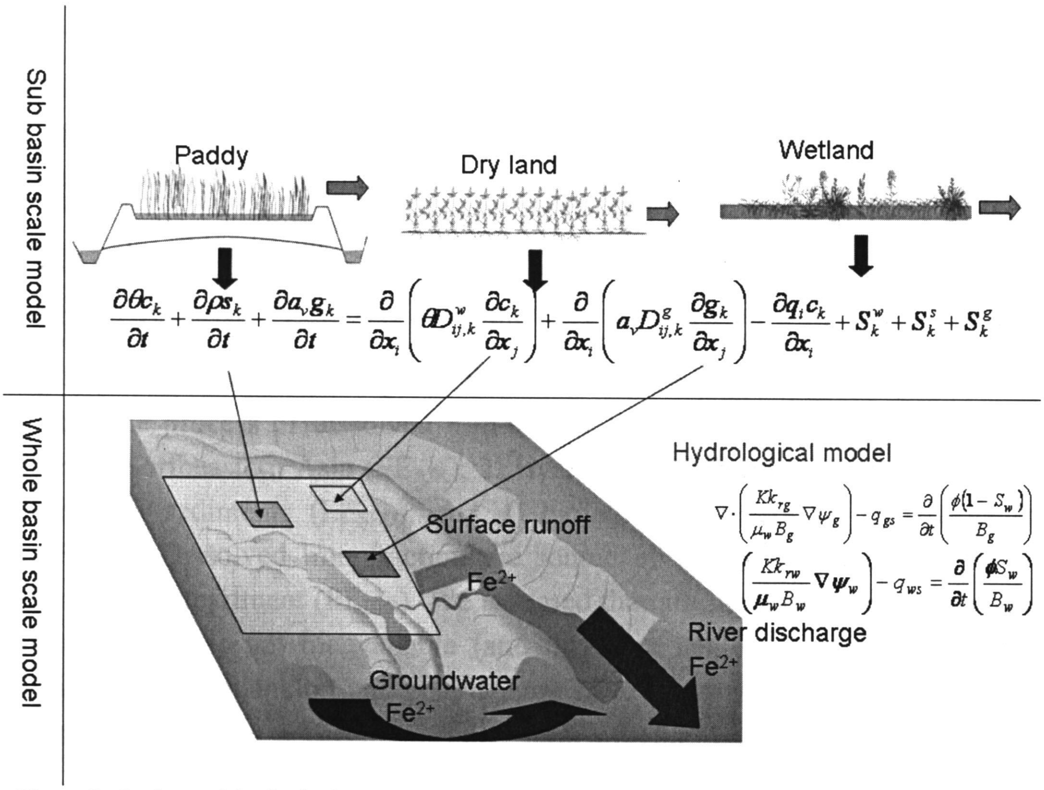

Figure7. Outline of the hydrological model which incorporate the mechanisim of dissolved iron production

4. SUMMARY

In this report, first, relationships between dissolved iron concentration of main tributaries of the Amur river basin and topographic indices of a catchment area of each tributaries are examined. There was no clear relationship between dissolved iron concentration and topographic index. It is supposed that other factors such as soil types or hydraulic conductivity are dominant to control dissolved iron concentration. Second, a possibility of impact of human activities on runoff regimes of the Amur river is examined using Student's t-statistics. The construction of the Zeya dam has no distinct impact on the discharge regime of the middle and lower reach of the Amur River. Third, outline of the hydrological model which incorporates dissolved iron transport mechanism is explained.

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