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# A SIMULATION STUDY ON THE SHRUNK WETLAND AROUND QINGHAI LAKE AND REGIONAL CLIMATE

WANG Han-Jie[1], JING Li, GAO Yun-Xiao

*(Key Laboratory of Regional Climate-Environment Research for Temperate East Asia, Chinese Academy of Science, Beijing* 100085, *China)*

**ABSTRACT:** Because of the increasing concerns about global climate change, it has been known by more and more peoples that there is a close relationship between wetland and/or peatland resources and climate change. This paper presents a new methodology to study the local climate variation caused by wetland shrinking around Qinghai Lake, the largest in-land salty lake in China, by use of a regional climate model (RCM) that commonly used in climate change study. The objective focuses on the regional climate effect of the shrunk wetland coverage in recent years. The results of numerical experiment showed that if the wetland coverage around Qinhai Lake were recovered as if in early 50s of last century, the regional climate in this area could be better with more cloud covers, higher relative humidity and more precipitation. In the other word, the area of wetland reduced is one of the most important reasons that caused regional climate aridification, eco-environmental deterioration and even desertification around Qinhai Lake.

**KEY WORDS:** climate change, wetland/peatland, sustainable development

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## 1 INTRODUCTION

Both wetland/peatland conservation and climate change have become our daily terms in the latest decades, their superficial relationship has been described by tremendous literatures and has been known to more and more peoples. Because of the big gap between disciplines of wetland ecology and climatology, the intrinsic relationship between climate change subjects and wetland conservation has not been revealed. Actually, there are few studies in climate-modeling related manner in the wetland ecological society so far though climate simulation prevailed since 70s of last century. There are more and more scientists, however, have noticed this problem and state that "the goal of protecting and wisely utilization wetland resource can not be achieved if the climate change process is not clearly understood; and any climate model could not be recognized as prefect if the wetland effect is not involved correctly (CHEN, 2003).

There are several ways to link wetland/peatland study with climate modeling, in which the most popular one is $CO_2$ source/sink study of wetland/peatland. Since $CO_2$ is the most important greenhouse gas and can be parameterized as a radiation forcing factor in climate model, any quantified $CO_2$ from wetland, either released or stored, can be formulated into climate model to reflect the wetland effects. According to Christensen, *et al*. (1999), There are significant amounts of carbon stored in their soil organic matter of the northern wetland and tundra areas. It was estimated that a total of 200 - 300 Gt of carbon is stored in the northern peatlands

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**Corresponding author:** Wang Han-Jie (1950 - ), male, Ph. D, Professor of Climate and Environment Research. E-mail: eerc2502@vip.sina.com

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and boreal forests amounting to about 30 % of total soil carbon stock (Post , *et al*. , 1982) in the world. The bulk of this carbon has been accumulated since the last glacial maximum and peatlands primarily at high northern latitudes have thereby consumed the equivalent of about 600 ppm atmospheric $CO_2$ (Adams , *et al*. , 1990) . The potential carbon release from tundra soils in the northern Eurasia are essential for improving global climate and carbon cycling models which are approaching a stage at which they incorporate potential feedbacks from carbon stored in terrestrial environments (Christensen , *et al*. , 1999) .

The stability of the stored carbon under changing climatic conditions has been the subject of recent concerned due to the expected climate warming , which is predicted to be the most pronounced in the northern continental regions (IPCC , 1996) . Since the carbon of wetland and tundra has been accumulated in prevailing cold and wet regions , a warmer and drier climate might cause a significant release of $CO_2$ , hence providing positive feedback on further climatic warming (IPCC , 1996 ; Billings , *et al*. , 1982 ; Billings , *et al*. , 1983) . A changed carbon balance in some tundra regions has already been reported (Oechel , *et al*. , 1993 ; Oechel , *et al*. , 1995 ; Malmer and Wallén , 1996) but there is little evidence as to whether this could provide any significant long-term release of carbon to the atmosphere. These kinds of study need worldwide scope $CO_2$ source/ sink database, global climate model (GCM) and supercomputation facility.

A rather simple way to link the wetland/ peatland resource to climate modeling is through dynamic wetland coverage. Getting into the satellite era , one can trace the dynamic variation of wetland/ peatland resource by satellite image. During past several decades, wetland around China was quickly shrunk either because of the climate aridification or the intensive human activity. Authoritative literature (DING and WANG, 2001 ; QIN and HUANG, 1998) reported that in the 20th century , the area of Qinghai Lake was shrunk 14 % from 4 980 $km^2$ in 1908 to 4 304 $km^2$ in 1986 ; the total wetland area around China was shrunk 50 % during the past 50 years (YU Gui-Rui , 2003) , the rapid shrinkage of surface area reflects long-term deficit in water budget flowing in. Wetland coverage deduction can be attributed to either climate aridification or human activities such as the up-reach reclamation or damming the wetland for farming. Taking the Tri-River (Yangtze River , Yellow River and Lancang River) Wetland as an example , there used to be more than 18 000 lakes , 180 rivers and large area of bogs, which formed the largest wetland around China and covered an area of 73 300 $km^2$ , But during the past 40 years , about 50 % of the lakes in Maduo county were dried up , the total area of Tri-River wetland was deducted 15 % from 1990 to 2000 according to the satellite observation (QIN and HUANG, 1998) .

The present study uses a prevailing climate model to simulate the possible effect of the wetland coverage variation around Qinghai Lake during past decades. The main objective is to quantify the effect of wetland coverage variation in climate modeling , which not only help people to understand the close relationship between wetland and regional climate change but raise the public awareness of wetland/ peatland conservation and sustainable management as well.

As one of the land use and land cover (LULC) type , wetland (peatland) affects the local climate environment inevitably. What we have known about the relationship between wetland/ peatland and climate change is:

1) Climate warming does affect the carbon cycle , coverage area , as well as biodiversity of wetland/ peatland ;

2) It is significant that areas of the wetland/ peatland have been shrunk by the climate warming or aridification not only , the human activities but also. (YU , 2003) ;

3) Large amounts of carbon were stored in wetland/ peatland in the history , it might be a significant carbon source if it is mismanaged by human being and

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would improve the climate warming;

Besides some ecological or biological views, wetland/peatland conservation or sustainable management is vital from the climate change point of view.

What we do not know very clear but it is important so far:

1) To what extent, the coverage variation of wetland/peatland during the latest decades, affects the regional climate?

2) How to parameterize the carbon cycle process of wetland/peatland and put its forcing effect into a climate model?

3) There are different types of wetland/peatland; the parameterization scheme should vary according to reflect their thermodynamic effect on regional climate.

Focused on the un-solved problems above, we use the latest regional climate model to simulate the possible regional climate variation as the wetland coverage being changed. The simulated area was highlighted on the wetlands around Qinghai Lake, which can be used as an epitome of Tri-River wetland that is essential for water budget of the mother river of Yellow and Yangtze River.

## 2 MODEL DESCRIPTION AND METHODOLOGY

### 2.1 The Numerical Model

The model used here is the fifth-generation Penn State-NCAR (Pennsylvania State University-National Center for Atmospheric Research) non-hydrostatic Mesoscale Model (MM5V3.6) (Grell, *et al*, 1994). With same structure of common meteorological models, MM5 has a wide variety of available parameterizations for the land surface, dynamics and radiation, which are flexible to parameterize the thermodynamic characteristics of wetland. In the result reported here, the non-hydrostatic option was selected with NCAR/CCM3 atmospheric radiation parameterization scheme, Anthes-Kuo cumulus parameterization scheme and BATS land surface scheme (Grell, *et al*., 1994). The model was initialized with a 3D meteorological field produced from the NCEP global analysis data set. The model interpolates the coarse resolution data to a fine grid of 15 km.

During a pre-processing step, terrestrial and meteorological data are horizontally interpolated from a latitude-longitude mesh to a variable high-resolution domain on a Mercator projection. The model then interpolates the grid pressure-level data onto 23 sigma levels from ground surface to the top of atmosphere and writes out the initial, time-dependent lateral boundary condition data for furthertime integration. Sigma surfaces near the ground closely follow the terrain, and the higher-level sigma surfaces tend to approximate isobaric surfaces.

In the results discussed in this paper, we have run the model over a numerical domain of 31.50°-42.50°N, 94°-107°E (Fig. 1), which covers the most part of Tri-River Wetland with the Qinghai Lake at its center. The integration is conducted for two months from July 1 to August 31 of 1998. The averaged value over the last 52-day period is reported here and the data of the first 10-day is removed from the average as usual because these data are easily affected by errors introduced by initial conditions. MM5V3 has been used for regional climate study by more and more authors (CHEN and Dudhia, 2001; Crawford, *et al*., 2001; WANG and JING, 2004). Although we do not have the capability to run a seasonal cycle since the computational expense and data handling requirements are extremely high, a two-month run provides an opportunity to explore the impact of wetland cover change on the regional climate.

### 2.2 Case Selection and Numerical Simulation

The wetland/peatland around Qinghai Lake was shrunk particularly by a mass movement of "damming the lake for agricultural production" and "drainage the peatland for pasture" in 60s - 70s of last century, which damaged large areas of the wetland/peatland. The latest statistics showed that the areas of Qinghai Lake and its adjacent wetlands have been shrunk 50% during the past 50 years (YU Gui-Rui, 2003).

In the simulation, the high-resolution 30-second

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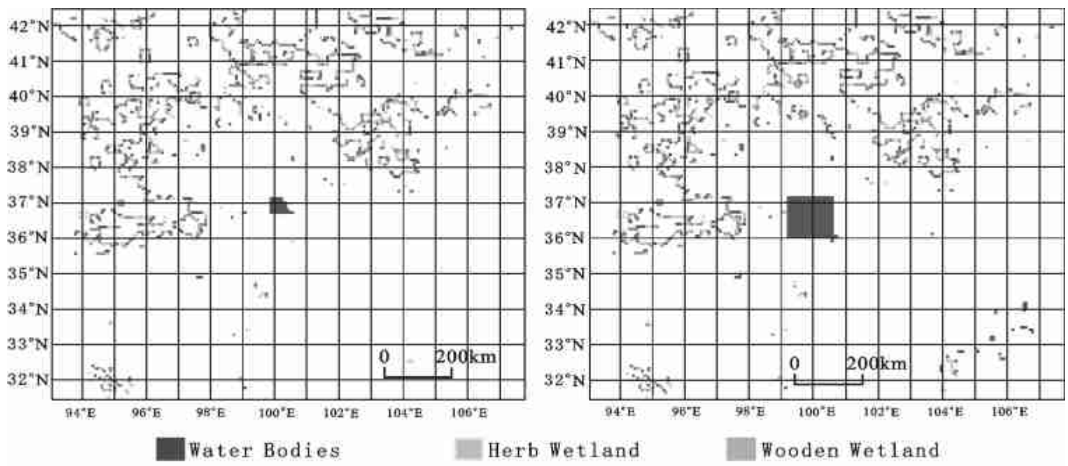


Fig. 1 Wetland around Qinghai Lake extracted from satellite database (left) and the virtual case for sensitive simulation study (right), in wetland coverage is restored as if back to the 50 s of 20$^{th}$ century

terrain data from the U. S. Geological Survey's EROS Data Center was used to characterize the land surface, which included the elevation data, 25-category global vegetation/land-use data, land-water mask data as well as various land surface parameters from a specific land surface model. Identified wetland/peatland included: irrigated crop and pasture, mixed dry crop and pasture, in land-water bodies, herbaceous wetland and wooded wetland, the corresponding thermal dynamic parameters of the LULC types are listed in Table 1 as used by Grell, *et al*. (1994).

The model is run for two wetland coverage sceneries, one is the actual case in which wetland coverage is extracted from the now used USGS data set, and another virtual case is assumed the present wetland and lake coverage being doubled as if in the 50s of 20th century, other schemes are the same in both model A and Model B. The former is referred to as control run (here after called scenery A) and the later is usually called sensitivity test (scenery B) in climate simulation study. Increased wetland coverage is shown in Fig. 1. The difference of the model outputs of scenery B and scenery A (scenery B - scenery A) are analyzed to reveal the possible climate effect of wetland/peatland.

## 3 RESULTS AND DISCUSSIONS

As mentioned before, wetlands/peatlands were shrunk around China was mostly caused by damming lakes for agricultural crops, which would change the thermodynamic characteristics of the underneath surface (Table 1). The data in Table 1 showed that as wetland turning into desertification land (from category 16 to category 2), the surface albedo was increased and the moisture availability was decreased significantly, the former means less solar radiation absorbed by water body and more solar energy to heat the air mass in surface layer, which was beneficial to the development of therm instability and consequently more cloudy and precipitation. The later was beneficial directly to the increase of air humidity and also cloud and precipitation formation. At the same time, destroyed wetlands were mostly herbaceous and wooded wetland with larger roughness length, the water body of the Qinghai Lake with small roughness length (Table 1) was reduced 14 % only. So, in average, the regional roughness length was reduced as different types of wetland changed into desertified land. The smaller roughness length, the weaker wind speed shear in the surface layer was. This restricted the development of unstable weather such as convective cloud, small scale squall and thunderstorm etc in summer time and finally reduced total cloud cover and precipitation.

Fig. 2 is the difference of averaged cloud cover between model outputs of Scenery A and Scenery B

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**Table 1 Thermodynamic parameters affecting the surface climate-environment through the climate simulation model**

| Land Use and Land Cover identification number | Land Use and Land Cover types | Albedo (%) | | Moisture avail. (%) | | Emissivity (% at 9 μm) | | Roughness length (cm) | | Thermal Inertia Cal $cm^{-2}K^{-1}s^{-1/2}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | sum | win | sum | win | sum | win | sum | win | sum | win |
| 3 | Irrg. Crop. past | 18 | 23 | 50 | 50 | 92 | 92 | 15 | 5 | 0.04 | 0.04 |
| 4 | mix. dry/ irrg. c.p. | 18 | 23 | 25 | 50 | 92 | 92 | 15 | 5 | 0.04 | 0.04 |
| 16 | Water bodies | 8 | 8 | 100 | 100 | 98 | 98 | 0.01 | 0.01 | 0.06 | 0.06 |
| 17 | Herb. Wetland (peatland) | 14 | 14 | 60 | 75 | 95 | 95 | 20 | 20 | 0.06 | 0.06 |
| 18 | Wooded wetland (peatland) | 14 | 14 | 35 | 70 | 95 | 95 | 40 | 40 | 0.06 | 0.06 |
| 2 | Dry land for crop and pasture | 17 | 23 | 30 | 60 | 92 | 92 | 15 | 5 | 0.04 | 0.04 |

(Scenery B-Scenery A) during the integration period, it showed that cloud cover was increased significantly, particularly in the southeast leeward area of Qinghai Lake; the largest value is 0.3. To the northwest windward area, however, there were some places where the cloud cover decreases, but the absolute value and the scope were very small. In general, the cloud cover was increased because of the increased wetland/ peatland coverage.

The increased wetland area caused increase of

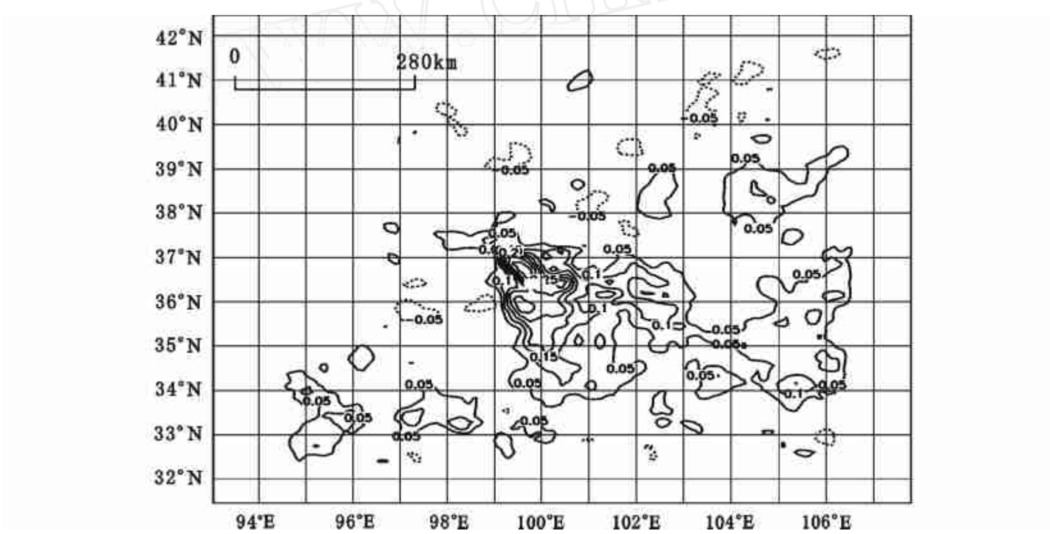


Fig. 2 The difference of cloud covers between Scenery A and Scenery B (Scenery B-Scenery A) (unit: decimal fraction)

surface air humidity, the simulation verified this assumption. Fig. 3 showed the difference between scenery A and scenery B in surface humidity. It is clear that the humidity was increased around Qinghai Lake as the wetland cover was increased. There was, however, a small area to the southwest of Qinghai Lake where the humidity decreased but at most numerical grids the humidity was increased.

Because of the increased humidity and cloud, the precipitation could be increased. Fig. 4 is simulated possible rainfall during the integration period, with a maximum of 2.1 mm/ d, the average value was about 0.4 mm/ d, which accounts for an increased rainfall of 24 mm (or 10 % more) in the two-

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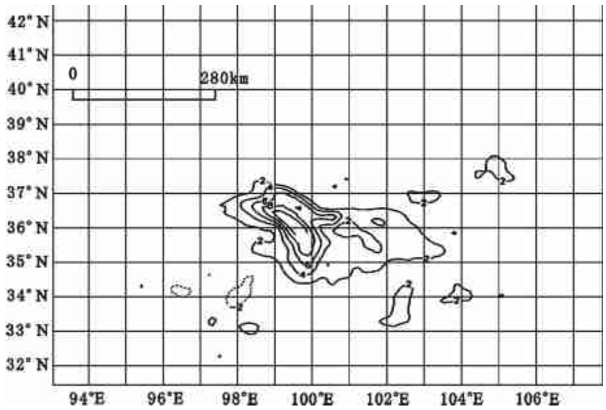


Fig. 3 The difference of surface humidity between Scenery A and Scenery B (Scenery B- Scenery A) (unit: %)

month integration period from July 1 to August 31. The climate average of rainfall in July and August near-by weather stations such Xining, Yushu, Dari, Gangcha, etc. was about 155 mm, which account for 15 % increment and is very helpful in this arid climate zone. It is expectable that, in the dry months other than July and August, the increment might be smaller, which needs more simulation studies to verify.

The center of increased humidity, cloud cover and precipitation was almost geographically identical in Qinghai Lake, in the other word; it is the wetland deduction that caused aridification and eco-environmental deterioration around Qinghai Lake. The simulation study showed if the wetland cover were restored as if in the 50 s, the regional climate could be improved by higher humidity, more cloud cover and more precipitation.

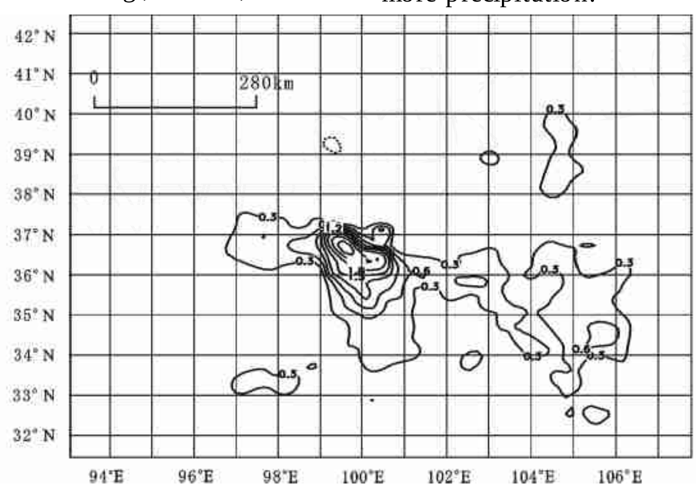


Fig. 4 The difference of possible precipitation between Scenery A and Scenery B (Scenery B- Scenery A) (unit: mm)

## 4 SUMMARY

The latest climate simulation model was used to simulate the possible regional climate effect around Qinghai Lake as if the wetland/peatland coverage around Qinghai Lake was restored as the actual case in 50 s of last century. The simulation showed that if the wetland/peatland was not destroyed, the climate in Qinghai lake area would be much more favorable for human being and eco-environment would be better than today. These included higher cloud coverage, air humidity and about 15 % more precipitation in summer months of July and August, which is very important to mitigate the aridification of Qinghai province. This revealed an interactive mechanism between wetland and regional climate. It has been verified by a lots of researches that the wetland coverage is decreasing under the background of global warming and human destruction. On the other hand, the variation of wetland coverage also affects the regional climate that contributes to the global climate change. The conclusion is that wetland recovery and conservation are important to regional climate. To the contrary, there would be a negative feedback mechanism between wetland and regional climate, the wetland declining causes deterioration of local climate which in turn destroys more wetland. We have been taught lessons about previous damming the lake for agricul-

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ture, drainage the peatland for pasture and the follow-up local environmental deterioration. Advisable policy is to protect the nature, and implement sustainable management within the valuable wetland/ peatland.

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