Hindawi Publishing Corporation
The Scientific World Journal
Volume 2014, Article ID 412183, 7 pages
http://dx.doi.org/10.1155/2014/412183

Research Article

Effects of Different Vegetation Zones on CH_4 and N_2O Emissions in Coastal Wetlands: A Model Case Study

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Received 8 March 2014; Accepted 21 March 2014; Published 29 April 2014

Academic Editor: Xu Gang

The coastal wetland ecosystems are important in the global carbon and nitrogen cycle and global climate change. For higher fragility of coastal wetlands induced by human activities, the roles of coastal wetland ecosystems in CH_4 and N_2O emissions are becoming more important. This study used a DNDC model to simulate current and future CH_4 and N_2O emissions of coastal wetlands in four sites along the latitude in China. The simulation results showed that different vegetation zones, including bare beach, *Spartina* beach, and *Phragmites* beach, produced different emissions of CH_4 and N_2O in the same latitude region. Correlation analysis indicated that vegetation types, water level, temperature, and soil organic carbon content are the main factors affecting emissions of CH_4 and N_2O in coastal wetlands.

1. Introduction

Methane (CH_4) and nitrous oxide (N_2O) are important active greenhouse gases contributing to global warming [1, 2]. Contributions of CH_4 and N_2O to global warming are 21 and 310 times of CO_2 [3] and occupy about 15% and 5% of greenhouse effects [4], respectively. Moreover, the two kinds of gases in the atmosphere are growing at 3% and 0.22% per year, respectively [5]. As an important source and sink of greenhouse gases, the coastal wetland ecosystems are important in the global carbon and nitrogen cycle and global climate change. Since coastal wetlands belong to the ecologically fragile zone [6], it is important to understand the relationships between vegetation characteristics and CH_4 and N_2O emissions.

Many studies on CH_4 and N_2O emissions in natural wetlands are carried out since the 1990s and focus on their emissions, absorptions, spatial and temporal variations, and environmental factors. Although the effects of vegetation features on CH_4 and N_2O emissions from wetland ecosystems worldwide have been investigated (e.g., [7–9]), these studies in our country are still relatively weak. In China, greenhouse gas emission flux and the effects of environmental factors are mainly concentrated on *Phragmites* wetland of the Sanjiang plain [10] and in the southern mangrove coastal wetlands [11, 12]. Recently, the spatial and temporal variations of N_2O and CH_4 fluxes associated with abiotic sediment parameters are quantified in the coastal marsh dominated by *Suaeda salsa* in the Yellow River estuary [13], and the effects of *different vegetation, Spartina alterniflora* and *Phragmites australis,* on CH_4 and N_2O emissions are investigated by using experimental mesocosms [9]. However, these studies do not compare roles of vegetation zone in different areas in CH_4 and N_2O emissions and future variations of CH_4 and N_2O emissions in coastal wetlands of China.

In this study, denitrification-decomposition (DNDC) model was used to simulate wetland biogeochemistry processes and its response to global warming in the four sites

of coastal zone distributing along the latitude. By simulation analysis, the following research questions were focused on the following.

(1) Are there differences in effects of different vegetation zones on CH_4 and N_2O emissions of coastal wetlands in different sites along latitude?

(2) How will CH_4 and N_2O emissions change with increasing temperature in coastal wetlands?

2. Materials and Methods

2.1. Study Areas. Four coastal wetlands were chosen in Sheyang, Dongtai, and Nantong of Jiangsu province and Chongming of Shanghai city (Figure 1). Each coastal wetland was divided into the bare beach, *Spartina* beach, and *Phragmites* beach according to vegetation type distribution.

Coastal zone of Jiangsu is affected by marine and continental climate. Average annual temperature is about 15°C. Average annual rainfall increases gradually from north to south, and average annual relative humidity decreases from south to north.

Chongming in Shanghai city is affected by subtropical marine monsoon climate. Average annual temperature is about 16°C, and average annual rainfall is about 1,030 mm.

2.2. Description of DNDC Model. The DNDC model takes denitrification and decomposition as the main processes applied in soil carbon and nitrogen biogeochemical cycles [14]. DNDC model has been applied in agriculture, forest, and grassland research worldwide for calculating soil carbon sequestration and greenhouse gas emissions [15]. This model consists of six submodels including soil, climate, plant growth, decomposition of organic matter, nitrification, denitrification, and fermentation process. Input variables of this model are soil properties, climate conditions, and agricultural production measures, and output variables are daily C and N content in soil and plant, soil temperature, and humidity data at different levels, and output variables are the emissions flux of CO_2, CH_4, N_2O, and NO.

2.3. Acquisition of Meteorological Data. Daily observation meteorological data in 1988 (for 80s) and 2004 (for 00s) are obtained from "China Meteorological Data Sharing Service System" (http://cdc.cma.gov.cn/). According to input data requirements, the daily maximum temperature (°C), the daily minimum temperature (°C), the rainfall data (cm), and other correlated data are turned into text format (ASCII encoding) and ready for input into the model. Future meteorological data are calculated by IPCC simulations.

2.4. Collection of Soil Parameters. Land use type and soil texture in this study are wetlands and silt loam, respectively, which were set directly in the options of DNDC model. Soil bulk density, soil pH, and surface soil organic carbon (SOC) content are obtained from literatures and field measurements measured in 2004. By inputting these soil data, the model would give other corresponding soil data, and default data would be used in this study.

2.5. Collection of Plant Physiological Parameters. In this paper, plant types included no plant (bare beach), *Spartina,* and *Phragmites*, which were not listed in the DNDC model. Therefore, we chose "0 Fallow" of the DNDC model to simulate a bare beach, while *Spartina* and *Phragmites* were created as new plant options. The two plant physiological parameters including biomass, C\N, LAI, and water requirement, for this model, were collected by literatures and field measurements in 2004.

2.6. Hydrological Data Preparation. The DNDC model provides four patterns to simulate the influence of flooding, including irrigation, rain-fed, observed water-table data, and empirical parameters. This study adopted observed water-table data pattern. Tidal data were obtained from tidal tables of the Yellow Sea and Bohai Sea, in 2004 and 1990, and Xiaoyang, Lvsi, Sheshan, and Sheyang port were chosen as tidal stations for Dongtai, Nantong, Chongming, and Sheyang, respectively. Every 10-day tidal height and tidal height datum of the port and the elevation of different wetlands were used to calculate the water levels of bare beach, *Spartina* beach, and *Phragmites* beach, which were made into water level table finally.

3. Results

3.1. Comparison of CH_4 and N_2O Annual Emission Flux of Different Beaches. The annual CH_4 emission flux of different beaches including Sheyang, Dongtai, Nantong, and Chongming has a similar trend between 80s and 00s (Figure 2), and similar phenomenon occurred for N_2O emission flux (Figure 3). The order of CH_4 emission ability in different beaches is *Spartina* beach > *Phragmites* beach > bare flat, while for N_2O the order is *Phragmites* beach > *Spartina* beach > bare flat (Figures 2 and 3). *Spartina alterniflora* and *Phragmites australis* increase CH_4 and N_2O emission fluxes contrasting with bare beach, which suggests that the vegetation type is one of the important factors affecting warm gas emission. CH_4 emission ability of *Spartina* beach is higher than *Phragmites* beach, while N_2O emission ability is contrary.

3.2. Comparison of Future CH_4 and N_2O Annual Emission Flux. Based on Figures 4 and 5, CH_4 and N_2O emission flux of three different coastal wetlands increase with increasing time from the present situation to 2100 in four study sites, which is consistent with the predicted trend of rising temperature (Figure 6). For different beaches, CH_4 emission flux of *Spartina* beach (MC) is > *Phragmites* beach (LW) > bare flat (GT), and N_2O emission flux of *Phragmites* beach is > *Spartina* beach > bare beach.

In different sites, CH_4 emission flux of CM and SY in MC and GT beach is higher than DT and NT, while on LW beach this trend is contrary. For N_2O emission flux, NT is the highest while SY is the lowest.

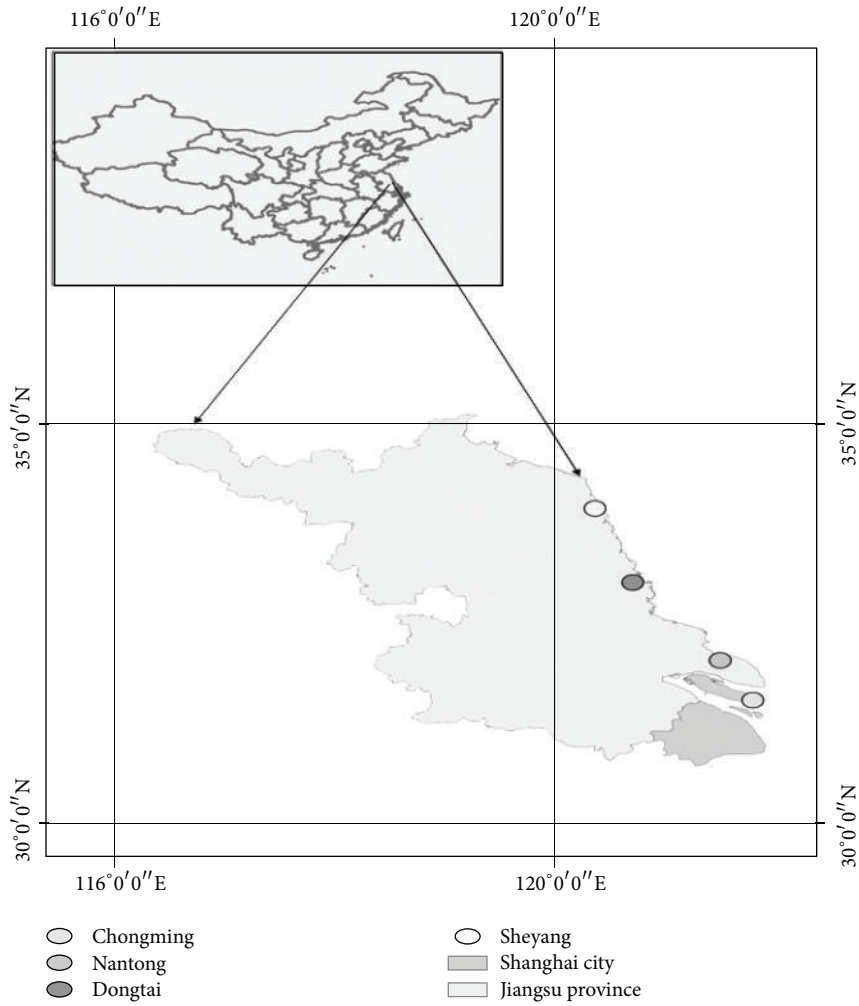

Figure 1: Locations of different sampling sites.

3.3. Roles of Different Factors in CH_4 and N_2O Emissions. By correlation analysis, CH_4 and N_2O emission flux are significantly correlated with soil organic carbon content ($R = 0.97$, $R = 0.695$ ($P < 0.01$), resp.) and with maximum biomass of per unit area ($R = 0.822$, $P < 0.01$; $R = 0.821$, $P < 0.01$). Soil pH has a significant correlation with CH_4 emission flux ($R = 0.362$, $P < 0.05$) and N_2O emission flux ($R = 0.402$, $P < 0.05$). CH_4 and N_2O emission flux have significant negative correlation with average water level ($R = -0.261$, $P < 0.05$; $R = -0.630$, $P < 0.01$).

Study results show that CH_4 emission flux in coastal wetland has significant correlation with temperature ($R = 0.707$, $P < 0.01$) and also is affected significantly by rainfall ($R = 0.379$, $P < 0.05$). N_2O emission flux is positively correlated with temperature ($R = 0.768$, $P < 0.01$); however, N_2O flux and total annual precipitation have no relevance.

4. Discussions

4.1. Roles of Similar Vegetation Distribution Zone in CH_4 and N_2O Emissions in Coastal Wetland along Latitude. Some studies showed that the emission of trace gases from wetlands was controlled by multiple factors like soil temperature, hydrology, and vegetation (e.g., [16–20]). Our study also indicated that vegetation, soil characteristics, and climate conditions affected emissions of CH_4 and N_2O in coastal wetlands. Moreover, it was noticeable that, at different sites along latitude, similar CH_4 and N_2O emission patterns were found, which was caused by similar vegetation distribution zone including bare beach, *Spartina* beach, and *Phragmites* beach in coastal wetlands. This indicated that vegetation was an important factor affecting greenhouse gas emission [21]. Van der Nat and Middelburg [22] found that gas emissions were affected collectively by vegetation type and species composition in tidal marshes, and increasing CH_4 flux was achieved by improvement of organic substrates and transportation of plant aerenchyma reducing oxidation of methane [23, 24]. Windham and Ehrenfeld [25] pointed out that, in two different tidal areas dominated by reeds and cattails, CH_4 emissions had some obvious differences. Exotic-species invasions affecting the vegetation structure of wetland ecosystems [25] would change the input of organic matter to soil [26]. Cheng et al. [9] reported that CH_4 emissions were significantly correlated with plant biomass and stem

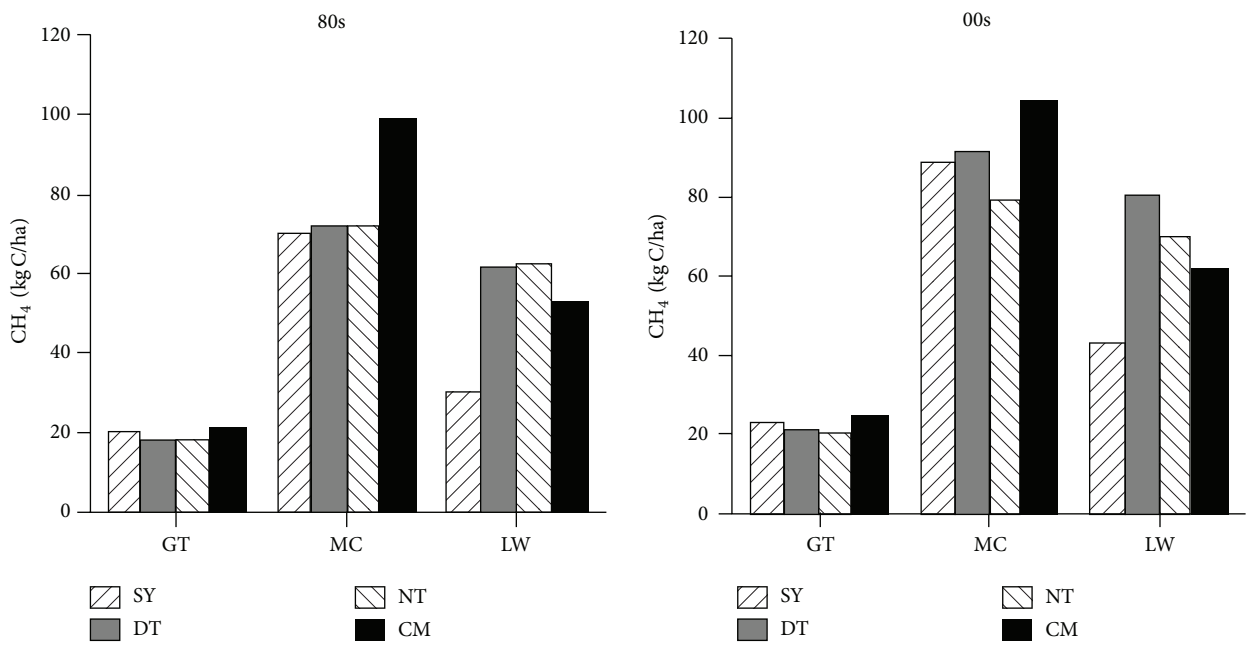

Figure 2: Comparison of CH_4 emission flux of different beach in 80s and 00s (SY, DT, NT, and CM represent Sheyang, Dongtai, Nantong, and Chongming, resp.; GT, MC, and LW represent bare beach, *Spartina* beach, and *Phragmites* beach, resp.).

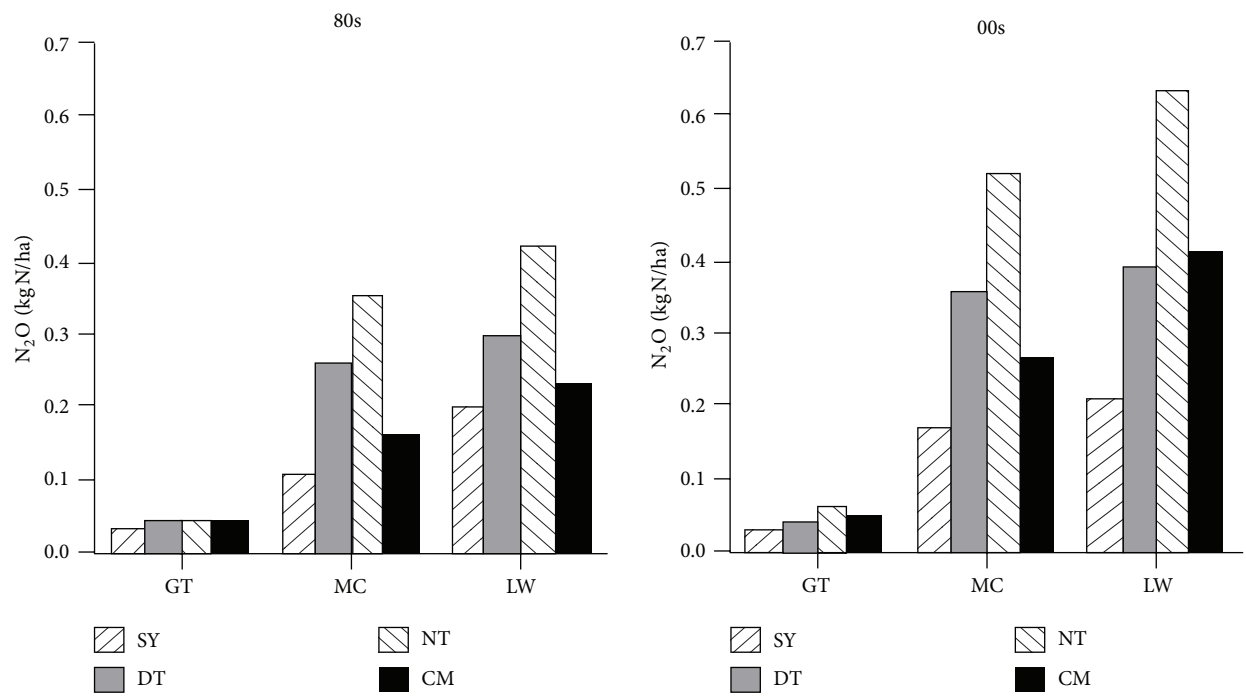

Figure 3: Comparison of N_2O emission flux of different beach in 80s and 00s (SY, DT, NT, and CM represent Sheyang, Dongtai, Nantong, and Chongming, resp.; GT, MC, and LW represent bare beach, *Spartina* beach, and *Phragmites* beach, resp.).

density for *Spartina* and *Phragmites,* while N_2O emissions were not accorded with this trend. Our model study also showed that, in a vegetation gradient zone, the effects of exotic-species *Spartina* on CH_4 emissions were more than native species *Phragmites* for its higher biomass and organic matter. However, this phenomenon did not exist in N_2O emission [27]. This was attributed to different mechanisms of CH_4 and N_2O emissions. Therefore, different vegetation distribution in coastal wetland was actually an important factor during the processes of CH_4 and N_2O emissions.

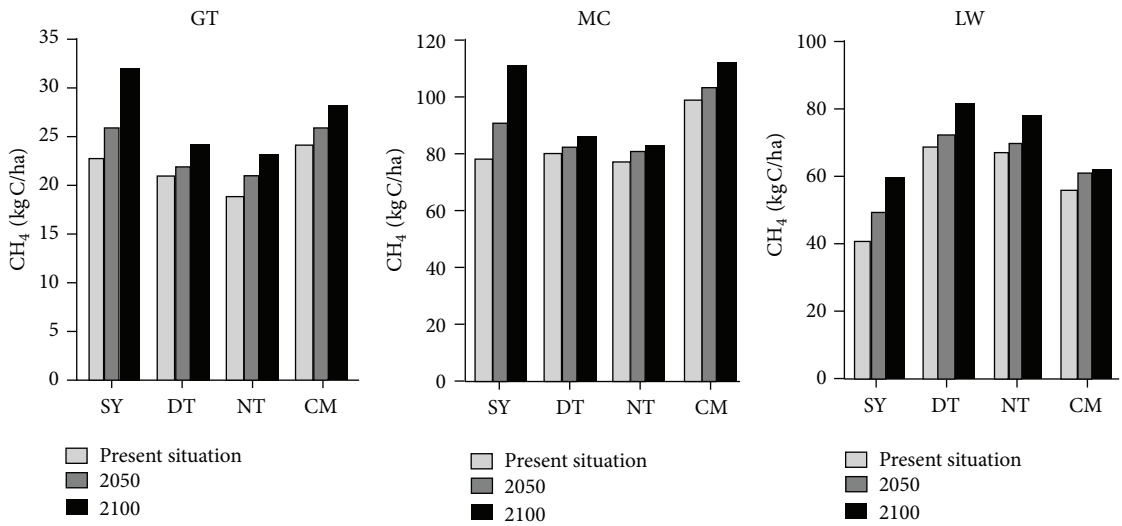

Figure 4: Comparison of present (average CH_4 emission flux of 80s and 00s) and future CH_4 emission flux of different vegetation zones at different locations.

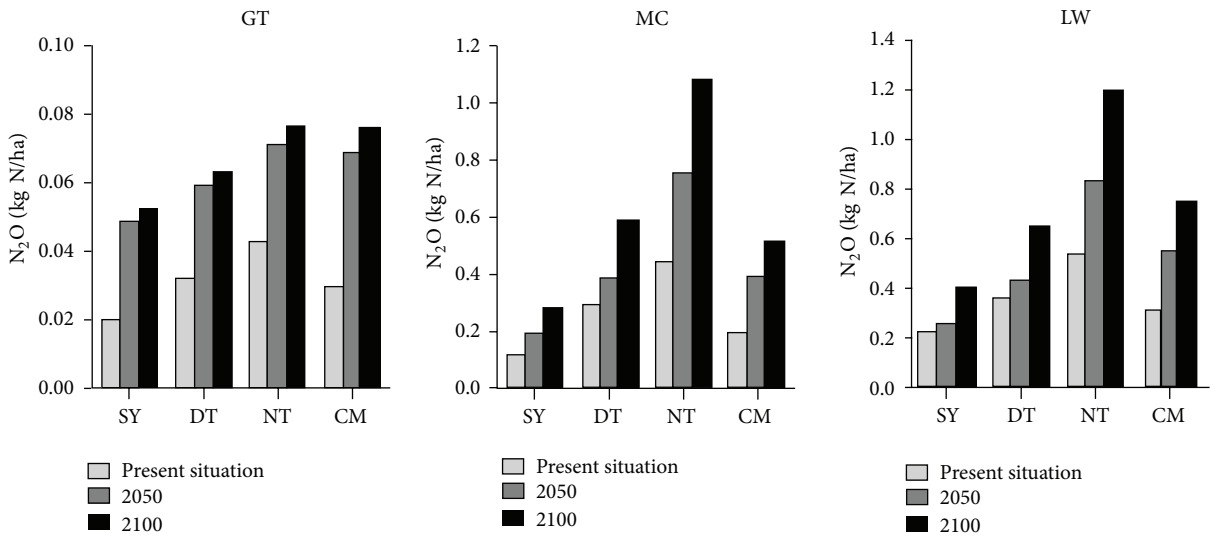

Figure 5: Comparison of present (average N_2O emission flux of 80s and 00s) and future N_2O emission flux of different vegetation zones at different locations.

4.2. Effects of Temperature on CH_4 and N_2O Emissions. The changes between present and future CH_4 and N_2O emission flux in the same site were mainly due to future temperature higher than present temperature. Temperature, especially soil temperature, played a very important role in CH_4 production and emission. Soil temperature directly affected the quantity, structure, and activity of a series of microflora that were involved in the process of the methane production and oxidation [7] and methane transport in soil [28]. Huttunen et al. [29] found that the correlation between CH_4 emission flux and peat surface temperature was most significant in all factors in the northern peatland, and incubation experiments also proved this relationship [30]. Our study results also showed that CH_4 emission flux in coastal wetland had significant correlation with temperature.

Hotness, humidity, and high carbon and nitrogen content of the soil were the best environment for N_2O production. The temperature was an important environmental factor in soil N_2O production and emission, but its relationship with N_2O emission was still controversial. Luo et al. [31] argued that temperature affected soil nitrification and denitrification, and Dorland and Beauchamp [32] found that, while temperature varied from −2°C to 25°C, the amount of the square root of the denitrification had a linear relationship with temperature. However, some studies also suggested that the temperature impact was not obvious. This study was consistent with the result of [33] that N_2O flux was positively correlated with temperature.

Comparisons of CH_4 and N_2O flux in different locations were complex. Multiple factors could cause the regional

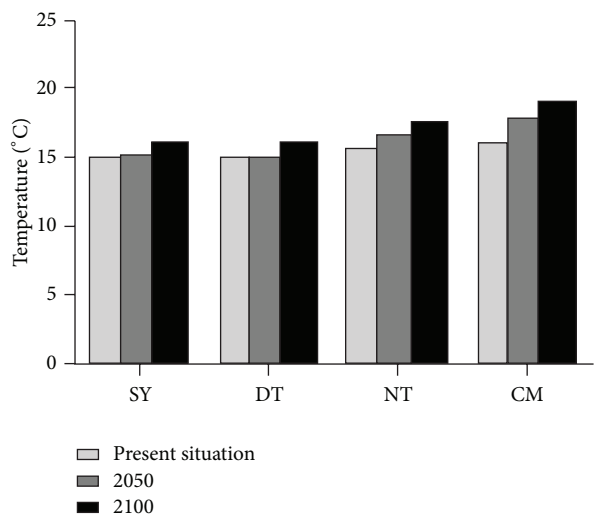

Figure 6: Comparison of present (average temperature of 80s and 00s) and future average annual temperature at different locations.

difference, such as temperature, rainfall, water level, and soil pH (e.g., [34, 35]).

5. Conclusions

By simulating CH_4 and N_2O emissions in the coastal wetlands by DNDC model, CH_4 emission ability of *Spartina* beach in three different vegetation zones was the highest, while the highest N_2O emission ability existed in *Phragmites* beach. This trend was very similar in the different sites including Sheyang, Dongtai, Nantong, and Chongming. By correlation analysis, CH_4 and N_2O emission fluxes were positively correlated with soil organic carbon content, temperature, and maximum biomass of per unit area and were negatively correlated with average water level. Comparisons of CH_4 and N_2O flux in different locations were complex, which were caused by multiple factors, such as temperature, rainfall, water level, and soil pH.

Conflict of Interests

The authors declare that they have no conflict of interests regarding the publication of this paper.

Authors' Contribution

Yuhong Liu and Lixin Wang contributed to this work equally.

Acknowledgments

This study was supported by the National Key Basic Research Program of China (no. 2014CB138802), National Key Technology R&D Program of China (nos. 2011BAC02B03 and 2013BAC09B03), the National Natural Science Funds of China (no. 31060076, 41261009), and the National Basic Research Program of China (no. 2013CB430405).

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