1-1-2018

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Recommended Citation
Lee, H., & Cheong, H.-W. (2018). Effects of Carbon Dioxide and Clouds on Temperature. Procedia Computer Science, 139, 95–103. https://doi.org/10.1016/j.procs.2018.10.223

Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 139 (2018) 95–103

Procedia Computer Science

www.elsevier.com/locate/procedia

The International Academy of Information Technology and Quantitative Management, the Peter Kiewit Institute, University of Nebraska

Effects of Carbon Dioxide and Clouds on Temperature

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Abstract

With the observed rise in temperature, many researchers have tried to identify the causes of such climate change to help mitigate its effects. The objective of this study is to determine whether, under the same carbon dioxide (CO_2) concentrations, CO_2 with lower cloud coverage would raise the temperature at a greater rate than CO_2 with higher cloud coverage. The hypothesis was tested through big data analysis and modeling. The relationships between the temperature and the CO_2 emissions, the temperature and the cloud coverage, and the CO_2 emissions and the cloud coverage were identified using the Pearson's correlation test. The data analysis concluded that the relationship between the temperature and the CO_2 emission is positively proportional with a significant correlation. The relationship between the cloud coverage and the temperature and the relationship between the CO_2 emissions and the cloud coverage were determined to be negatively proportional with significant correlations. For modeling, the temperature increased more rapidly as cloud coverage shrank. The results supported the hypothesis that the cloud coverage mitigates warming effects created by CO_2 emissions.

Keywords: Cloud coverage; Carbon dioxide; Temperature

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Peer review under responsibility of the scientific committee of The International Academy of Information Technology and Quantitative Management, the Peter Kiewit Institute, University of Nebraska.
10.1016/j.procs.2018.10.223

1. Introduction

The temperature of the Earth is determined by the balance between the input and output of energy [1]. In other words, if the energy coming in from the Sun and the energy escaping out of the Earth by emitting radiation to space were in balance, the Earth's temperature would remain constant [2]. However, according to the Intergovernmental Panel on Climate Change (IPCC), the average global temperature has risen roughly 0.85ºC in the last 100 years (IPCC, 2013). In addition, the last three decades from 1983 to 2012 were said to be the warmest period of the last 1400 years; the term for such trend is called climate change [2]. Thus, the temperature of the Earth has risen, and it is because of the energy imbalance [2].

As the amount of energy coming from the Sun is relatively constant, most scientists agree the main cause of the current global warming is the anthropogenic increase in the greenhouse gases that trap the energy radiation from the Earth toward the space (IPCC, 2007). Among other greenhouse gases, carbon dioxide (CO_2) gets most of the attention as the key element of the Earth's climate system [3]. For example, Delworth et al. [4] claimed that the doubling of carbon dioxide had influenced many regions, especially the tropics, with an increase in temperature. For the future, IPCC (2007) estimated that Earth would warm between two and six degrees Celsius over the next century, depending on how fast the carbon dioxide emissions grow. Given the effects of CO_2 have on radiation and climate change, many researchers and policymakers have focused on finding the CO_2 reduction targets to lessen its effects [2].

While the question of what to do about future climate change has been pending, some researchers saw cloud coverage as a potential factor of temperature change. Carslaw, Harrison, and Kirkby [5] suggested that variations in the intensity of galactic cosmic rays in the atmosphere would alter in cloud coverage, leading to change the temperature of the Earth.

However, the effects of clouds on temperature are uncertain so many studies have tried to identify whether the cloud coverage has a negative or a positive feedback to the warming effects. For example, Dessler [6] concluded that cloud coverage has a positive effect on the temperature. Likewise, Clement, Burgman, and Norris [7] and Lauer et al. [8] claimed the cloud has a positive effect over the eastern Pacific. Spencer and Braswell [9] even claimed not carbon dioxide but cloud cover causes global warming. On the other hand, McLean [10] claimed that the reduced cloud coverage from 1987 to late 1990s accounts for the rise in temperature since 1987. Similarly, Kauppinen, Heionen, and Malmi [11], discussing the impact of cloud cover on the temperature, claimed that one percent increase in low cloud cover decreases 0.11 degree Celsius.

Based on these studies, solutions related to clouds were proposed to lessen climate change. For instance, Lomborg of Copenhagen Consensus Center came up with a proposal to develop cloud whitening technology to reflect solar radiation [12]. Similarly, Russell [13] claimed cloud brightening research had merit in combating global warming. Since these recent studies have reflected the importance of clouds to the climate, it is time to verify the correlations among the CO_2 emissions, the cloud coverage, and the temperature and identify the impact of clouds.

2. Experimetal Setup

China was chosen as the region for data analysis since it released the largest amount of CO_2 [14]. However, as China is the third biggest country in the world, the region was limited to be Northeast China to reduce the error. Since the CO_2 emissions data were not limited to a specific region of China, the uncertainty was taken into account. The seasonal temperature and cloud coverage data over Northeast China and annual CO_2 emissions data from China were used for data analysis.

The monthly temperatures of Northeast China from 1909 to 2012 was acquired from Osborn and Jones [15, 16]. The data contain monthly mean temperatures over Northeast China. The data report the temperatures to the hundredths place in degrees Celsius.

The seasonal coverage of clouds over Northeast China during 1951-1994 were acquired through the work of Kaiser [17]. The cloud data were excerpted from a database of daily weather observations provided by the National Climate Center of the China Meteorological Administration. The data were received from 196 Chinese stations. To minimize errors, Kaiser differentiated daytime and nighttime observation since it is troublesome to accurately measure the cloud coverage when the sky is dark. The cloud coverage was averaged for each station over four seasons.

The annual emissions of CO_2 in China from 1751 to 2008 were acquired from the Carbon Dioxide Information Analysis Center at Oak Ridge National Laboratory, which is supported by the U.S. Department of Energy [14]. The data were found on the Carbon Dioxide Information Analysis Center homepage. The authors analyzed the trends for the CO_2 along with the data.

NetLogo is simple but well equipped with the features necessary for modeling climate change [18]. NetLogo visualized the interactions among variables related to climate change. The available factors of NetLogo are the sun-brightness, albedo, cloud coverage, and CO_2 concentration. The carbon dioxide concentration, sun-brightness, and albedo were control factors and left constant. The cloud coverage was set as the dependent factor in the model while the temperature was observed as the explained variable. The cloud coverage was set to be the independent factor because the hypothesis attempts to observe how the cloud coverage mitigates the warming effects of carbon dioxide. The temperature change was observed over time, and the unit of time was set as ticks. The temperature was observed after given 1103~1124 ticks.

3. Results

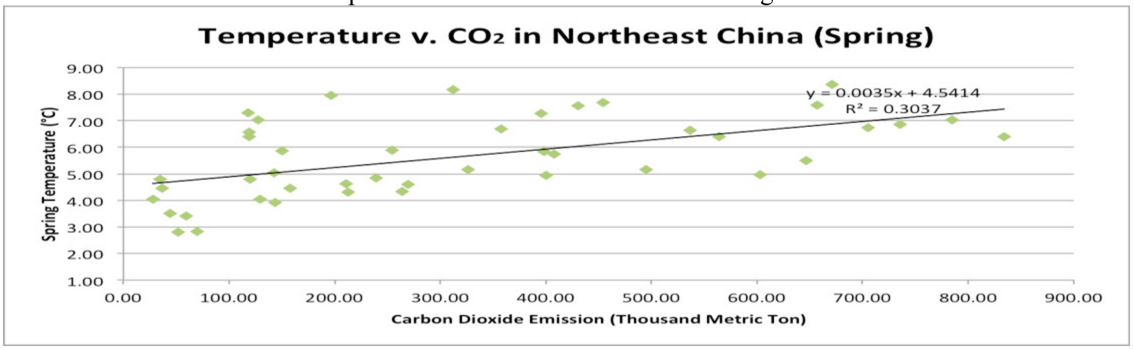
The Pearson's correlation test was used to verify the correlation between the carbon dioxide emission and the temperature. As shown in Fig. 1, the correlation coefficients were 0.5511 for spring, 0.4446 for summer, 0.4300 for fall, and 0.4666 for winter. Positive correlation coefficients indicate that the carbon dioxide and the temperature have a positive relationship. The coefficients of determination were 0.3037 for spring, 0.1976 for summer, 0.1849 for autumn, and 0.2177 for winter. The coefficient of determination calculates the percentage of value that can be predicted and is acceptably high. The absolute values of correlation coefficients were greater than the critical values over all seasons, 0.3008. Therefore, the hypothesis that the temperature was related carbon dioxide emission was supported by the data with the confidence interval of 0.05.

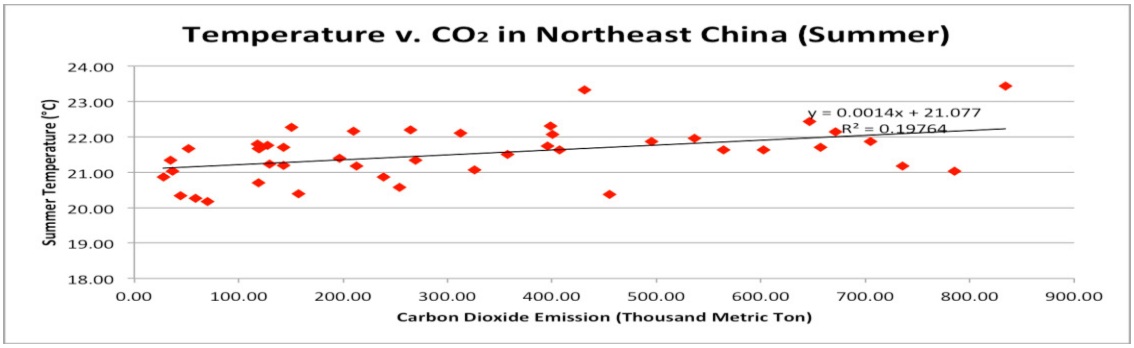
The Pearson's correlation test was also used to determine the correlation between the cloud coverage and the temperature. As shown in Fig. 2, the correlation coefficients were -0.5276 for spring, -0.6180 for summer, -0.4517 for autumn, and -0.3106 for winter. Negative correlation coefficients indicate that cloud coverage and temperature have a negative relationship. The coefficients of determination were 0.2783 for spring, 0.3819 for summer, 0.2040 for autumn, and 0.0964 for winter. The absolute values of correlation coefficients were higher than the critical values over all seasons, 0.3008 for spring, summer, and autumn and 0.3044 for winter. Therefore, the hypothesis that the temperature was related cloud was supported by the data with the confidence interval of 0.05.

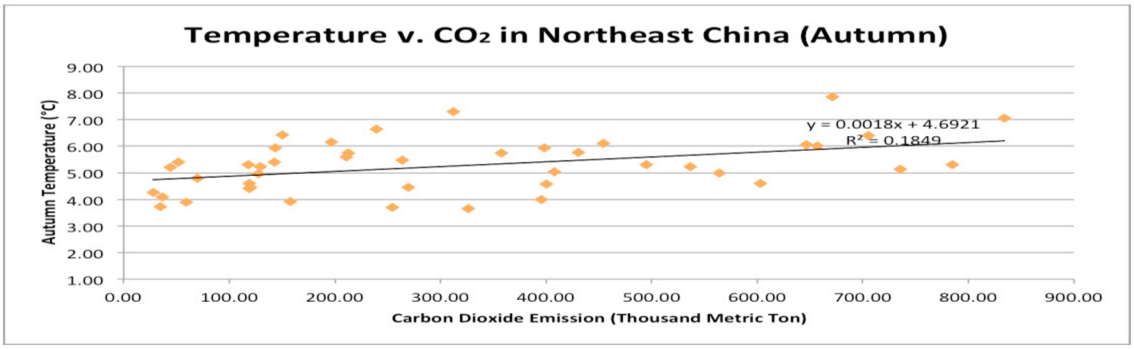
The Pearson's correlation test was also used to check the correlation between the carbon dioxide emission and the cloud coverage. As shown in Fig. 3, the correlation coefficients were -0.5967 for spring, - 0.4718 for summer, -0.3749 for fall, and -0.4015 for winter. Negative correlation coefficients demonstrate that carbon dioxide emissions and cloud coverage have a negative relationship. The coefficients of determination were 0.3561 for spring, 0.2226 for summer, 0.1406 for autumn, and 0.1612 for winter, which is an acceptable number for r2. The absolute values of correlation coefficients were higher than the critical values over all seasons, 0.3008 for spring, summer, and autumn and 0.3044 for winter. Therefore, the possibility that carbon dioxide could be the factor of the cloud coverage is supported by the data with the confidence interval of 0.05.

In the model shown in Fig. 4, for 0 percent cloud coverage, the temperature increased rapidly. The temperature increased from 12.0°C to 20.3°C over 1103 ticks. For 23.24 percent cloud coverage, the temperature increased sluggishly compared to the temperature increase with 0 percent cloud coverage. The temperature increased from 12.0°C to 15.3°C over 1115 ticks. For 44.53 percent cloud coverage, the temperature increased less rapidly compared to the temperature increase with 23.24 percent cloud coverage. The temperature increased from 12.0°C to 12.9°C over 1113 ticks. For 73.86 percent cloud coverage, the temperature barely increased from 12.0°C to 12.1°C over 1124 ticks. For 100 percent cloud coverage, the temperature stayed constant from 12.0°C to 12.0°C over 1108 ticks.

The trend was observed that temperature decreased as the cloud coverage rose.







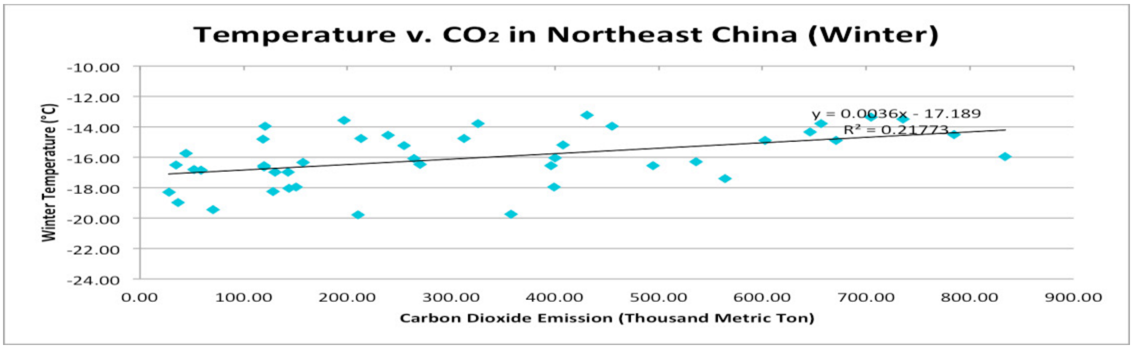
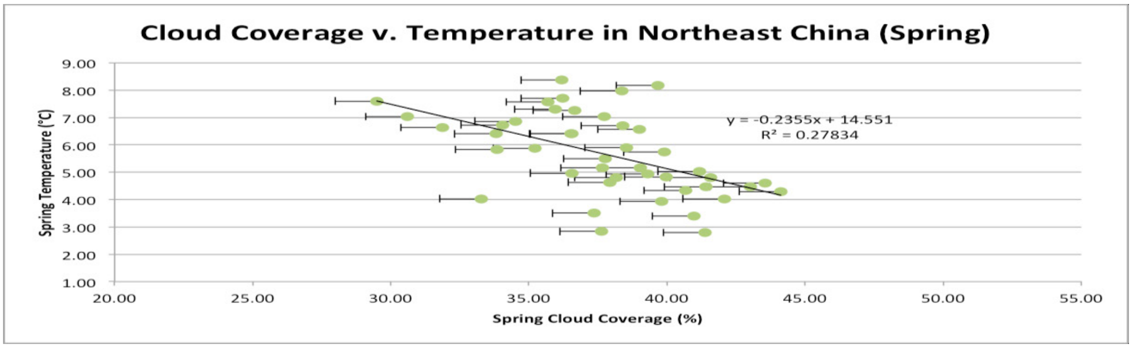
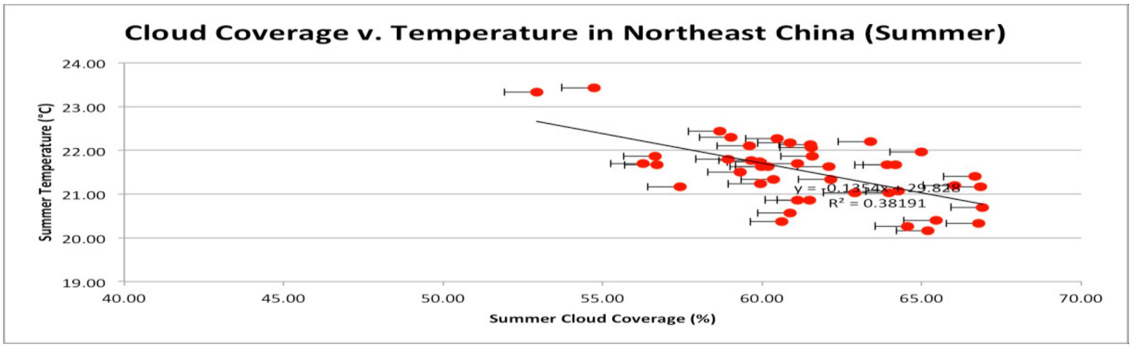
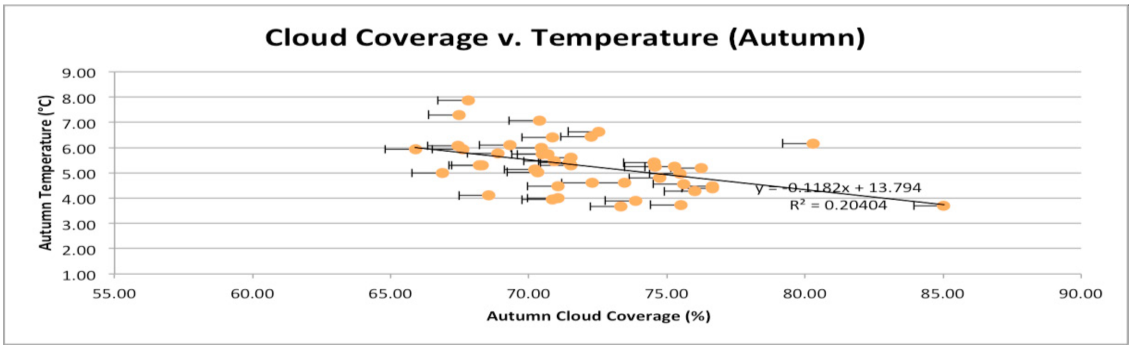


Fig. 1. The carbon dioxide emission vs the temperature over china during 1951-1994 in spring, summer, autumn and winter







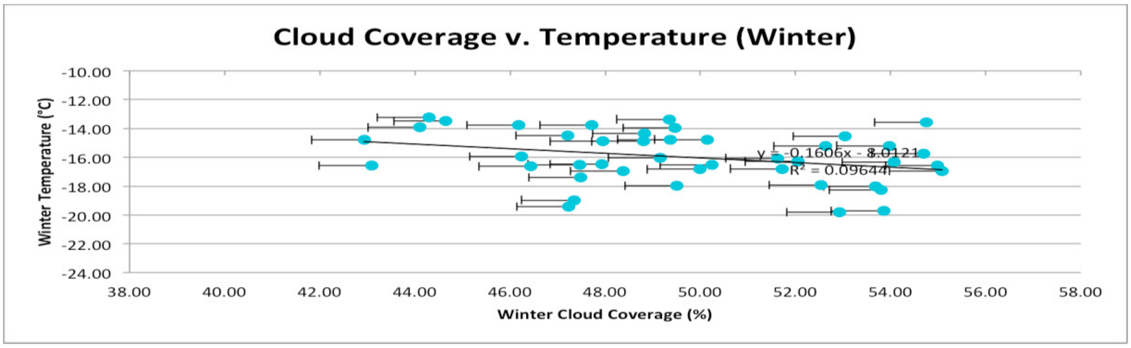
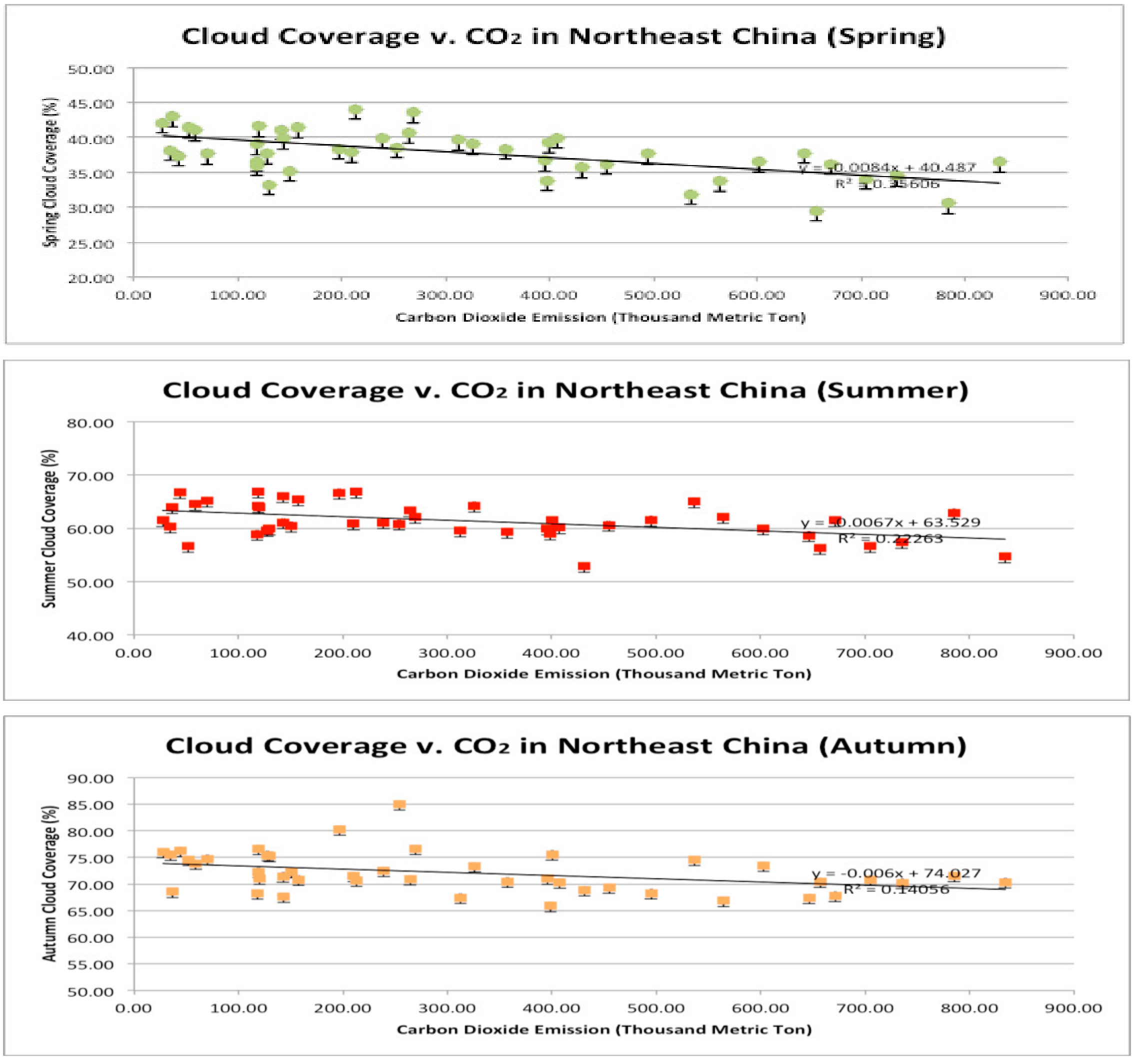


Fig. 2. The cloud coverage vs the temperature over china during 1951-1994 in spring, summer, autumn and winter



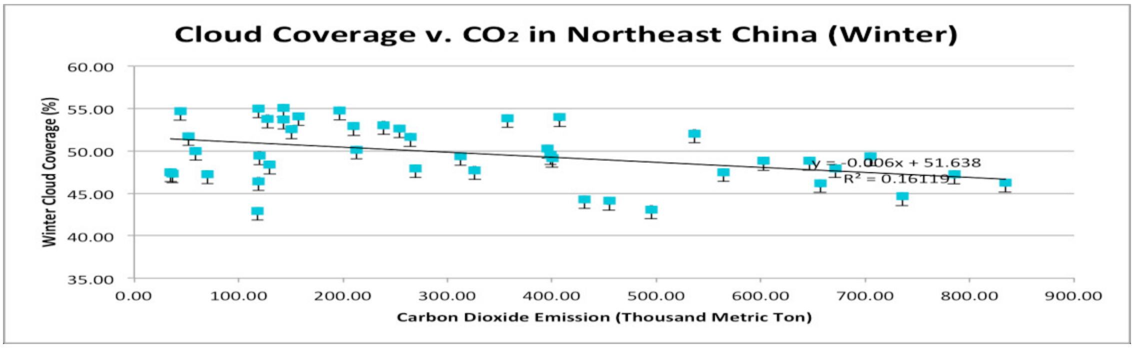
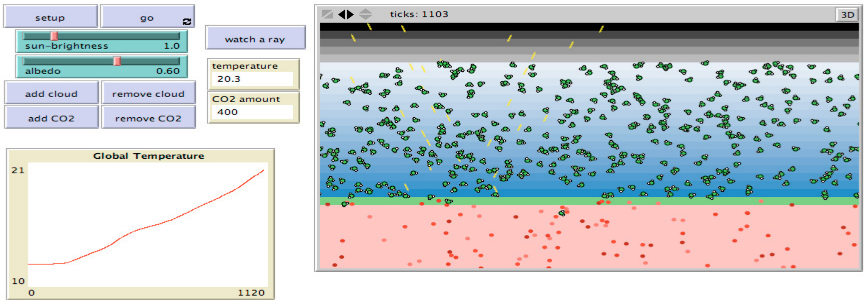
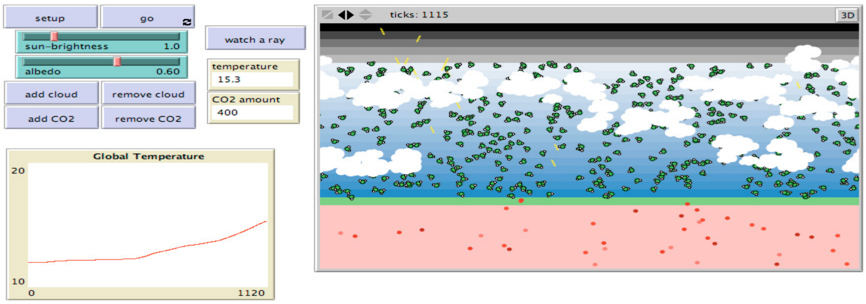


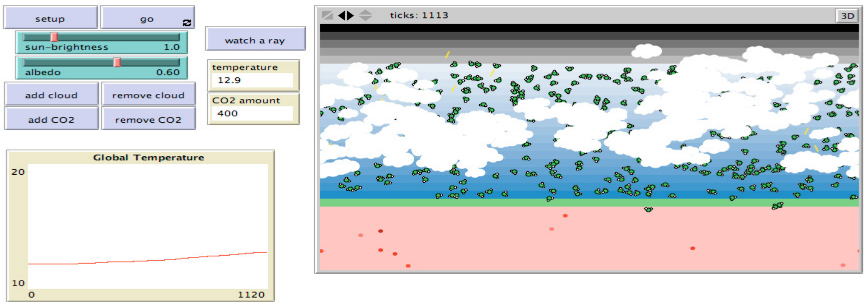
Fig. 3. The carbon dioxide emission vs the cloud coverage over china during 1951-1994 in spring, summer, autumn and winter



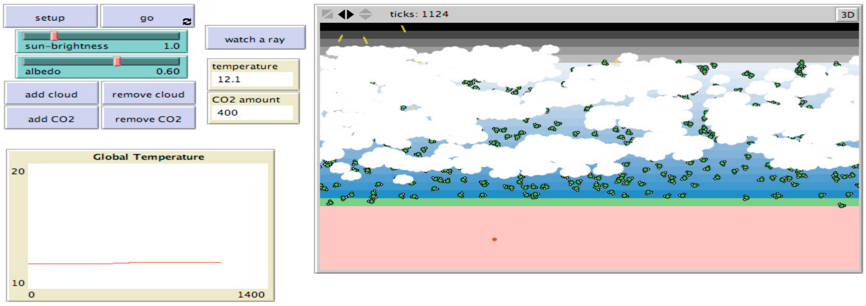
(a)



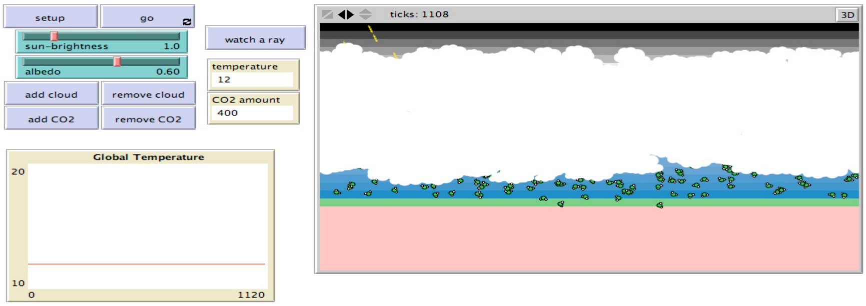
(b)



(c)



(d)



(e)

Fig. 4. (a) 0.00percent (b) 23.24percent (c) 44.53percent (d) 73.86percent (e) 100percent cloud coverage

4. Conclusion

The objective of the research was accomplished through the Pearson's correlation test and modeling. The Pearson's correlation test demonstrated the validity of the hypothesis for correlations between three factors, temperature, carbon dioxide emissions, and cloud coverage. The critical values for Pearson's correlation were smaller than the absolute values of all correlation coefficient with 95% certainty; thus, the null hypotheses were rejected.

The initial hypothesis was that the warming effects from the increase in CO_2 would be mitigated more with the increase in cloud coverage than by the reduction in CO_2 emissions alone. The project hypothesis was confirmed with the confidence interval of 0.05 through the Pearson's correlation test. However, the research raises uncertainties whether clouds are dependent upon carbon dioxide emission or the temperature is dependent upon both carbon dioxide emission and cloud coverage. Although the question remains unanswered, the trend is being shown with the cloud coverage over time; the decrease had been going on for over 43 years and is certainly notable. Therefore, although model approved that the cloud coverage has an influence over the temperature, the idea that cloud may be dependent upon carbon dioxide emission arises. In conclusion, the reduction of carbon dioxide emission could lead to the multiplication of cloud coverage, and since both factors are accountable for temperature change, the temperature will decrease in greater amount. The research suggests reduction in carbon dioxide could lead to killing two birds with one stone, affecting both cloud coverage and temperature.

The limit of the research lies in the uncertainties in the data and lack of details in the data set. The errors of the carbon dioxide data and the temperature data were not provided. Also, the specifications for the cloud data are deficient. The cloud coverage data does not specify the kind of clouds. Lauer et al. [8] stated that warming effects differ by cloud types. Thus, although the research concluded that the cloud coverage had a negative effect on temperature, further research is recommended to specify cloud types.

The research could be extended further also by testing whether carbon dioxide emission affects cloud coverage. Although the research put forth Pearson's correlation test to test whether carbon dioxide emission, and temperature, cloud coverage and temperature, carbon dioxide emission and cloud coverage had correlations, it did not determine whether one caused the other.

Therefore, if extended research were done to determine the factors, mitigation of climate change could be achieved more efficiently.

Acknowledgements

This research was supported by the MSIT(Ministry of Science and ICT), Korea, under the ITRC(Information Technology Research Center) support program(IITP-2018-08-01417) supervised by the IITP(Institute for Information & communications Technology Promotion)

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